GEOMETRIC SOLUTION FOR TARGETING AIRBORNE DF RESOURCES

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THESIS

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ABSTRACT

The ability of an airborne direction finding (DF) system to accurately fix target emitters depends heavily on the aircraft/target geometry and the duration of target emissions. Based on this, a computer model was developed to aid in the study of the effects of system parameters on fixing success and to help in constructing a procedure for finding optimum search patterns.

The development of the computer model is traced from its foundation in current technology to its evolution into an interactive computer graphics system. With the computer model studies were made of the effect of one, two and three aircraft on fixing success. Also, simulation of DF missions using two aircraft were used to study the effects of target signal duration and target position on fixing success. As a result of the study a procedure using interactive graphics was developed to find optimum or near optimum patterns of flight for various airborne DF missions.

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I. INTRODUCTION

The purpose of airborne direction finding (DF) is the acquisition and location of sources of electromagnetic (EM) radiation. Acquisition encompasses the detection and monitoring of a target radiator. Location involves the execution of several good quality cuts on a target and the successful reduction of those cuts to a target location.

Many computer models have been designed to make this airborne acquisition and location more effective. Typically for direction of arrival (DOA) interferometer systems, most models dwell on the analysis of the "cuts" or lines of bearing (LOB's) taken by the aircraft. This type of analysis is a follow on to the fixed site DF models, where system error in LOB's was minimized by statistical analysis. Unlike fixed sites, however, airborne DF has the added advantage of mobility to improve its effectiveness in locating targets. To capitalize on this mobility a computer model was formulated which would help find optimum flight patterns for airborne DF missions, using one, two or three aircraft.

Optimizing the manner in which aircraft are deployed against a target provides the greatest opportunity for improvement of success in target acquisition and location. Ultimately in any DF system the ability to locate a target depends on the data produced for input to the statistical reduction programs. It would seem most reasonable then that

an investigation of the interaction of flight and target parameters with acquisition and location success would be productive.

The target acquisition and location program is modelled around present airborne DF technology and the environment in which it would most likely operate. Targets are treated as either known or unknown. Known targets are flown against for the best DF cuts, and unknown targets are searched for methodically to give the highest probability of acquisition. Aircraft can be flown against both known and unknown targets simultaneously, but as Chapter IV discusses, a compromise must be accepted since they are somewhat in opposition to one another.

The investigation, at times, focuses on the effectiveness of airborne DF against three types of emitters classified as repetitive pulse, short duration and long duration emitters. A typical scenerio involves two aircraft flying along a 200 mile track about 30 miles from territorial boundary. A primary target exists beyond the border with a two minute on-time per aperiodic transmission. Besides the primary target a secondary search role is given the DF aircraft for new targets in the 150 by 200 mile area surrounding the primary target.

The computer-graphics model is programmed to permit an analyst to rapidly weigh the advantages or disadvantages of different sets of flight parameters in this scenerio. The variation of scenerios is limited only by the bounds of the

model programming, which was written to allow for wide application. The next chapter discusses the development of the model and the factors affecting it.

In Chapter III the programming of the model and its mechanical operation are discussed along with some of the algorithms describing the model. The results of the work completed with the program follow in Chapter IV, with conclusions following in Chapter V.

II. DESIGN OF THE CONCEPTUAL MODEL

A. CURRENT AIRBORNE DF

Preliminary work was done investigating the current trends in airborne DF and the possible courses DF might follow in the near future. It was found that new DF airborne systems possessed considerable sophistication beyond that of Vietnam conflict vintage systems. Aircraft were being selected that could fly above 20,000 feet and in excess of 200 nm/hr. It is judged that technology in this field would also support aircraft flying above 60,000 feet and flying in excess of 300 nm/hr. Aircraft of the capabilities listed could easily carry the DOA interferometer, frequency scanning receivers, and navigation equipment necessary to support a DF mission. It is conceivable that other sensors could be included to supplement the DF package. The operation of the system would most likely be remoted to save on onboard weight and allow control and mission coordination to be exercised at a distant location. For example, using a four-thirds earth model (discussed in Section C) it can be shown that remoting on VHF is possible under ideal conditions at a distance of 86 nautical miles for an aircraft at 5,000 feet or to a distance of 245 nautical miles for one at 40,000 feet.

As DF aircraft are assigned to higher altitudes, the better the link range and the greater the permissible search area of the DF aircraft without using communication relays

will become. The improved aircraft and better DF equipment extend not only the capability of an airborne DF unit, but also the tactics needed to improve success. For example, multiple aircraft coordinated against the same target or search area can help insure good quality fixes on short duration signals by providing the necessary space diverse LOB's. Also, high flying aircraft can be tasked to search large areas of hostile territory at a distance by virtue of their long sensor view to the EM horizon.

B. MODEL FRAMEWORK

Preliminary work was initiated to build the above observations into the framework of the model. The elements of the problem were first drawn into a simple representation shown in Figure 1a. This was then modelled in Fig. 1b and Fig. 2 to provide analytical information about the problem.

Figure 1b shows that the border was linearized for simplicity, and range circles introduced. The range circles represent the maximum distance at which the aircraft can DF electromagnetic signals. The shaded area is the EM field of view (FOV) common to both aircraft. As a figure of merit this area indicates how well an area is being searched for short duration signals (any target radiator in that area has a high probability of being cut by two aircraft simultaneously). Other overlapping fields of view will exist if a third plane is added. Note that the area between the aircraft track and border was not counted as contributing to the area of coverage, since it is nonproductive.

Figure 2 shows that Fig. 1a was further modelled to indicate the aperature of a two aircraft fix on a known target radiator. The distances from the aircraft to the target are also shown. Both aperature and aircraft to target distances also provide simple figures of merit. The closer the aperature approaches 90° the better the chances of a successful fix. The distance from aircraft to target is a necessary measurement indicating whether the target is within fix range.

C. SYSTEM FACTORS

With the framework model completed work was initiated to quantify and model the factors affecting an airborne DF scheme. These factors, it was found, could be grouped into (1) earth geometry factors, (2) navigation factors, (3) target to aircraft link factors, and (4) DF remoting link factors.

1. Earth Geometry Factors

The terrestrial environment of the airborne DF system presents some initial problems regarding the distance at which emitters can be detected and the accuracy of the parameters used to describe the system. The problems stem from the fact that the spherical earth's curved surface introduces a horizon for line of sight signals and makes distance, aperature, and area measurements somewhat complicated. To live with the consequences of curved surface geometry in the model would be difficult, so solutions were sought that would simplify the modelling without serious loss of accuracy.

Detection range was finally established by assuming targets were emitting in the VHF and above range with sufficient power that they could be detected at the horizon. To conform to the observed propagation characteristics of line of sight signals this horizon was modelled to be the horizon of a four-thirds earth. Reintjes and Coate in Ref. 1 show that the distance to this "radar horizon" is

$$d = \sqrt{2h_a} + \sqrt{2h_e} \qquad (1)$$

where d = distance to horizon in status mile

h_a = aircraft altitude in feet

h_e = emitter altitude in feet

In general the emitter altitude could be considered zero.

Equation (1) provides a starting point for estimating detection ranges which would allow the perimeter of the field of view of the aircraft to be established. It was recognized, however, that this was only an estimation, and was included in the model for use when better data for an estimation was unavailable.

Other difficulties in working with a curved surface were eliminated when it was determined that the surface could be modified without significant deterioration in accuracy. Equation (1) helps provide the basis for a simplification of the spherical earth to a flat earth model. Coburn in Ref. 2 shows that for altitudes up to 80,000 feet, the location of a target ratiator at the radar horizon (340 nmi) would be off by less than .5 percent if a planar rather than a spherical model was used for the fix. Since the planar or flat earth

model is vastly less difficult to work with, it greatly simplifies the calculation of areas, aperatures, and aircraft to emitter distances.

2. Navigation Factors

The question arises whether or not aircraft position error significantly affects the ability of airborne units to accurately fix targets. Obviously, large error would make fixing a highly difficult and largely a statistical process. It must be assumed, however, that an advanced airborne DF system would possess the best navigation equipment available in an effort to minimize navigation error. It is possible, then, that newer systems such as differential Omega would be selected over the older Tacan system which often is not sufficiently accurate.

Deverin in Ref. 3 concludes in a preliminary investigation of DOA airborne DF fixing error that if the position error is small fixing accuracy will not be significantly degraded. It then follows that with newer navigation systems aperature, distance to target, and overlapping field of view areas need not be treated statistically, but can be treated deterministically with position error neglected. This was incorporated into the model.

3. Target to Aircraft Link Factors

To accurately model the airborne DF system, modifications had to be made to previous assumptions on the target to aircraft signal link. It was decided earlier that equation (1) would suffice in describing the link range for cases

where either good line of sight conditions existed or a rough estimation was wanted. The model would, however, be deficient if link factors were not considered and a more complete alternative to equation (1) found for more accurately determining the emitter detection range (and consequently the aircraft field of view). Equation (1) would still serve the aforementioned purpose, but the alternative procedure would provide closer adherence to the physical situation when necessary.

Several factors from target transmission characteristics to aircraft antenna and receiver capabilities affect the signal link. These factors have been assembled below and their significance in the model analyzed. The result of this analysis is the link model shown in Fig. 6.

In considering the major factors that affect the link, target transmission characteristics are most plainly of prime importance to the problem. Target signal power, for instance, can vary from zero to more than enough for detection at the horizon. Power also can be radiated by directional antennas and signals polarized vertically, horizontally or some place in between. Modulation types like AM-SSB can present signals of lower average power than equal peak power continuous wave signals like FM. Frequency, as shown by the Fig. 6 equation, can also affect the range of the signal.

Most of the problems presented by the transmission characteristics above can be greatly compounded if the target transmits in aperiodic short bursts or is surrounded in close

proximity by other targets. The problem of burst transmission is one problem for study by this paper. The other problem of sorting targets in close proximity, however, has been investigated by Pfendtner in Ref. 4 with mixed results, altogether not too encouraging.

Propagating forth toward the DF aircraft the target signal experiences free space loss as well as numerous environmental losses. Man made noise, rain attenuation and shadowing from mountains are a few of the factors interfering with the ultimate receipt of the signal. Figure 3 shows that these factors were able to be modelled as contributing losses and expressed quantitatively in the link equation.

Upon arrival at the aircraft signal detection becomes a matter of technological capability. Much of the model substance depended on the design of the advanced airborne direction finding system.

One of the important advances modelled was in interferometer design. Figure 4 shows the antenna patterns for an existing system. The almost perfectly circular pattern of antenna gain in the horizontal plane allowed the electromagnetic field of view around the aircraft to be modelled as the circles illustrated in Fig. 1b. Definitely a major contributor to simplifying the model. However, the antenna patterns shown in Figs. 4b and 4c initially gave concern that signal attenuation for even small depression angles might severely obscure the aircraft's field of view. A small calculation relieved the uncertainty by showing that even with

a total blackout of signal beyond a 20° down depression angle for an antenna at 24,000 feet, only a circle of 11 miles radius around the aircraft would be affected. Considering the view to the EM horizon is 190 nautical miles not very much area is affected, even in this extreme case.

One other observation was also found pertinent to the interferometer analysis. A distortion of the field of view could occur in steep aircraft turns. Consequently, this maneuver was discouraged for the flight being modelled.

Besides the consequences of the antenna patterns there are miscellaneous errors introduced into the system by re-radiation of reflection that affect DOA measurements and ultimately calculated aperatures. These errors do not materially affect the model as long as they are small compared to the mean aperature measurements (typical error due to all causes $\pm$ 2°).

The DF receiver section fed from the interferometer must provide the sensitivity necessary for handling low power signals and resulting low signal to noise ratios. This signal-to-noise ratio is critical to the confidence factor of the LOB's executed. The relation is:

$$\theta_{RMS} \propto \sqrt{S/N}$$

where θ_{RMS} is the root mean square of the radian error. For the aircraft part of the link model it was decided that the radius of the EM field of view should be based on the capability of the receiving equipment on board and the degree of

confidence desired in the LOB's. Given an emitter signal strength the radius of the field of view could be calculated in the Fig. 3 link calculation.

4. DF Remoting Link Factors

Beyond the requirement to have an airborne system capable of executing accurate LOB's there must be a communications system capable of relaying the data back to a collection center. That relay requirement meant the model had a restriction imposed on the distance the aircraft could fly from the collection center or its intermediate relay terminals. Contingent on a sufficiently powerful aircraft transmitter and high gain transmit antenna the aircraft could maintain two way contact with the collection center on VHF out to the radar horizon under the best conditions. The model, then, was further constructed to operate under this constraint or tighter ones if the conditions warrant it.

III. COMPUTER MODEL DESIGN

A. COMPUTER MODEL REQUIREMENTS

The complexity of the airborne DF problem dictated that a computer model be derived from the initial modelling work to help provide insight and aid in the analysis of the DF system. This computer model had to reflect both the airborne DF system and sound modelling principles. The model, then, had to consist of an analytic representation of the system in program form, containing the crucial parameters of the problem without the minor or irrelevant system factors involved that unnecessarily complicate the problem. The model also had to accept variable inputs and yield readily assimilated results on command.

With the above in mind this phase of the modelling was begun by constructing a computer program in FORTRAN consisting of all the necessary problem elements. The completed program was to be run on a XDS 9300 computer and data output on a line printer and Adage graphics display terminal. This type of modelling proved to be quite effective in providing rapid data processing and display, and consequently a high degree of man-machine interaction. The details of the program formulation and its eventual use in a responsive computer directed system are given in the following sections.

B. CONSTRUCTION OF MODEL PROGRAM

The computer program had to accurately represent the model upon which it was based. Faithfulness to concepts and analytical expressions of the model was of utmost importance in the program design. These concepts and expressions are expanded upon as the discussion of the program construction continues.

The computer program can be described in broad terms by the rough flowchart shown in Fig. 5. Apparent is the separation of the program into input, data generation, and output sections.

1. Input Section

The input section was designed to allow pertinent problem parameters to be input via punched card at the beginning of program execution. These parameters are:

1. Initial position of aircraft along track
2. Altitude of aircraft or distance to electronic horizon
3. Velocity of aircraft
4. End points on track for each aircraft
5. Time of flight
6. Time increment for calculation of output data

The input section also includes the primary method of input which is teletypewriter. This will be discussed later.

2. Data Generation Section

a. Basic Flight Data

The data generation commences with the receipt of input parameters. As shown in Fig. 5 several operations

must be performed on the input before processing is complete. A few initial tests are performed to set the program up for an electromagnetic field of view overlap. Programming must first determine if the field of view of one of the three aircraft has the field of view of one or both of the others totally enclosed, as would occur with aircraft at different altitudes and in near proximity. If so a calculation of that inclusive area is made. This area is corrected for any unproductive area between the aircraft and a border beyond which lies the region of interest. A correction is also made so the area of overlap is weighted only with the common field of view of two planes, i.e., although three aircraft may have a certain field of view in common, the common area is counted only once as in the two aircraft case with no extra consideration for the third aircraft. Figures 6a and 6b show the cases where two plane and three plane totally inclusive fields of view occur.

After the tests for the special cases of total inclusion are performed, the test for the more general case of overlapping fields of view is carried out. If there is found to be overlap, a number of steps are begun to accurately find the overlap area. First, the X-Y intersects of the overlapping circles enclosing the two fields of view are found (See Fig. 6c). This is done by solving the two circle equations simultaneously for X and the Y. With the value of X the area of the overlap can be found by treating the overlap as the sum of two circle sectors (program actually deals

with half circles, i.e., area to one side of track). Thus in Fig. 6c the area is the sum of sectors A and B. The formulas are:

$$\text{SECTOR A} = (R2)^2 \cos^{-1}(1-H2/R2) - (R2-H2)\sqrt{2(R2)H2-H2^2} \quad (2)$$

$$\text{SECTOR B} = (RR)^2 \cos^{-1}(1-HR/RR) - (RR-HR)\sqrt{2(RR)HR-HR^2} \quad (3)$$

$$\text{TOTAL AREA} = \text{SECTOR A} + \text{SECTOR B} \quad (4)$$

Variations of the above formulas are generally adequate to accurately determine overlapping area, although two situations exist where the above area needs correction. The first situation occurs when a border is introduced into the problem as described previously. A trigonometric correction function was found and added to the area formulas. This made the particular formula above more general without degrading its accuracy.

The second situation occurs whenever the complicated overlap case shown in Fig. 6d occurs. The program was designed to find the field of view overlap of two aircraft at a time. Normally, the whole common overlap area of two fields of view would be unique to two aircraft as in Fig. 6c. However, in the Fig. 6d case all three aircraft cover portions of the same area. That is, in calculating the common overlap two planes at a time the piece of area common to all three planes would be counted three times, thus resulting in an erroneous value for area. The field of view common to all three planes then had to be found and subtracted twice from resulting area. Again this was done trigonometrically for reasons of ease and accuracy.

The next part of the data generation section is used to calculate aperatures and distance from aircraft to target. The basic formula for calculating the aperature between two aircraft was derived from analytic geometry and as an example consists of the following for aircraft one and two.

$$\text{APERATURE} = \text{TAN}^{-1} \quad \frac{M_2 - M_1}{1 + M_1 M_2} \tag{5}$$

M_1 - slope of line of sight from aircraft one to the target

M_2 - slope of line of sight from aircraft two to the target

The formula is adjusted by the program to yield positive angles from 0 to 180 degrees. The distance from each aircraft to the target is figured simply as the length of the hypotenuse of a right triangle, the hypotenuse having an aircraft and the target as end points. Figure 2 illustrates the above.

b. Statistical Data

The last part of the data generation section is used to compile statistics on the DF flight modelled by the program for aircraft two and three (one not used). Knowledge of the geometry and mathematics involved in the compilation will help in the utilization of the statistics, as well as help in understanding their limitations. Figure 10 shows the statistics calculated.

The first set of statistics under "SEARCH MODE" is calculated independent of any target being specified. Statistic one is based on the aperature between the two aircraft, with the angle vertex at one of two points. If the

midpoint of the field of view perimeter arc of one aircraft lies within the field of view of the other, the aperature is measured with the angle vertex at that midpoint. Otherwise the vertex is at the perimeter intersect of the two fields of view. Figure 7a shows an example of the latter. With the definition so established, the input parameter IANGX is compared to the aperature generated for each increment (INCR) of time in the flight. A percentage is then computed based on the number of times the aperature was greater than IANGX. Statistic two in this set compares the input parameter PSA to the percentage of the search area covered for each increment of time in the flight. Figure 7b shows that area is defined as the total area beyond the border visible to the lowest flying aircraft if it travels the entire permissible aircraft track. This search area, divided into the common overlapping area and multiplied by 100, is the percentage of search area covered is greater than PSA. The third statistic (unnumbered) in the set finds the percentage of search area covered during the entire flight. As opposed to the previous statistic the percentage computed here represents only new areas not counted during previous increments of time. That is, statistic two could reflect the same overlapping area counted over and over again. There is no aircraft movement implied by statistic two. However, the third statistic uses the scheme shown in Fig. 7c to establish whether a certain area has been viewed simultaneously by both aircraft. One hundred equally spaced points along the border represent the search area. At

each incremental time during the flight the points are checked off in a matrix and not recounted. The number of points checked off in the matrix at the end of the flight equals the percentage of search area covered.

The second set of statistics under TARGET MODE is totally dependent on a target specification (XP1, YP1). If a target is not specified the statistics are compiled for a target at XP1=0.0, YP1=0.0. Statistic one of this set indicates the percentage of time the target was in view of both aircraft when checked at incremental (INCR) periods during the flight. Statistic two indicates the percentage of time with the target in range the aperature on the target was greater than the input parameter IANG. Again, the above condition is checked at incremental periods during the flight. The third statistic indicates the percentage of time the target is within the viewing range of two aircraft if the views need not be simultaneous by the aircraft (as in statistic one) and they have the time specified by the input parameter INM to get into range. This check is made incrementally (INCR) during the flight with each aircraft moved indpendently INM minutes ahead at increments of INCR and tests made to see if the above criteria is fulfilled. For the most accurate results INM should be an integer value times INCR, since the program generates data only at INCR increments.

3. Output Section

The output section of the model program was designed to display the airborne DF system parameters and program

generated data as effectively as possible. The data was formulated for output to a graphics terminal and to a line printer for hardcopy. One of three graphs may be displayed on command; time versus area, time versus aperature, and the possibility of a two plane fix on a target versus time. A display indicates the function switches to be pressed for the different graphs. Once a graph is selected a display appears with the graph on several lines listing the system parameters. An option box accompanying each graph contains the options available to the user. One of the options is hardcopy from the line printer. Essentially the same information is presented in the printer output as on the graphics display, but in addition to the graphs, tabulated data is given. The specifics of the graphics display and line printer hardcopy are given in Appendix A which contains a detailed description of the program in use.

IV. RESULTS

The interactive graphics computer program was used to produce the quantitative data necessary for insight into the nature of the airborne DF problem. To this end numerous sets of data on several facets of airborne DF were generated and tabulated to establish patterns and provide a base from which techniques for optimization could be derived.

A. SELF-APERATURE

One of the first areas of airborne DF to be examined was the effectiveness of self-aperature. That is, how effective was one aircraft against targets which only radiated for a short period of time. In this examination the computer model was used to fly an aircraft against two targets, one in close proximity and one fairly distant. The scenerio is typical with the following initial system parameters:

	ALTITUDE(FT)/RADIUS(NM)	VELOCITY(MPH)	INITIAL POSITION*
AIRCRAFT 1	0 / .0	.0	.0
AIRCRAFT 2	24000 / 190.2	160.0	2.7
AIRCRAFT R	24000 / 190.2	160.0	.0

DISTANCE TO BORDER IS 36.0 MILES

IF SPECIFIED, TARGET CO-ORDS ARE X = 120.0, Y = 150.0

TOTAL AIR TIME IS 300 MINUTES

TURNING POINTS ARE X = 0.0 AND X = 240.0

* Positions are given as an X coordinate position along the permissible aircraft track.

The target is considered to be in full view for each entire transmit period. Aperature data is tabulated for four of these transmit periods in Table I. Note that aircraft two's position is aircraft R's position n minutes later. Evident from this data are the poor aperatures attainable against targets emitters of short duration. For example, the target at 40 nm from the aircraft track must transmit for over five minutes to be fixed with an aperature greater than 20 degrees. Also, the target at 160 nm must be transmitting for greater than 20 minutes before a 20 degree aperature fix is possible.

The results of this first examination infer that a better scheme is necessary if good aperatures for high confidence fixes are to be produced against short duration targets. The next step then was to examine two and three aircraft systems, and determine their effect on airborne DF.

B. TWO AND THREE AIRCRAFT COMMON AREA COVERAGE

It was initially conceived that one of the most important measures of the ability of a two or three aircraft flight to fix target emitters was the size of the common field of view they maintained. This follows very simply from the fact that if a short duration signal is to be detected by two aircraft simultaneously the source must be within the common field of view of both aircraft. Thus, any target emitting within that overlapping field of view area has a good probability of being cut at least twice. When searching for emitters, then, the size of the overlapping area becomes an important consideration.

Intuitively it follows that the more aircraft employed the better the coverage. To find out how much better, the three aircraft in the model were utilized to fly two search missions, the first with the following parameters:

	ALTITUDE(FT)/RADIUS(NM)	VELOCITY(MPH)	INITIAL POSITION
AIRCRAFT 1	0 / .0	.0	0.0
AIRCRAFT 2	24000 / 190.2	-160.0	240.0
AIRCRAFT R	24000 / 190.2	160.0	.0

DISTANCE TO BORDER IS 36.0 MILES

IF SPECIFIED, TARGET CO-ORDS ARE X = 120.0, Y = 40.0

TOTAL AIR TIME IS 300 MINUTES

TURNING POINTS ARE X = 0.0 AND X = 240.0

The second mission was flown similarly but with the following exceptions:

ALTITUDE OF A/C 1 24000

INITIAL POSITION OF A/C 1 = 120.0

Using this scenerio it might initially be spectulated that a three aircraft flight had a 33 percent coverage edge over a two aircraft flight. Table II however, shows that even though the maximum coverage during the flight was the same for both, the median overlapping coverage with three aircraft was 60 percent higher than for two. Using the median as a figure of merit it appears that the increase in coverage is not at all linear with the increase in the number of aircraft.

C. TWO AIRCRAFT COVERAGE OF KNOWN TARGETS

Part B primarily addresses the situation where targets exist randomly in an area under search. Another situation exists, however, where the location of some emitters is approximately known. The fixing of a known emitter is trivial since two aircraft can fly to keep its approximate location in view at all times and cut it whenever a signal is present. Under normal circumstances, however, it is probable that there will be a need to cover many known targets as well as search for unknown emitters. This requires the aircraft move in a search pattern but still give attention to a known primary target or cluster of targets. Based on this, a scenerio was created which would allow the effects of the variables concerning known targets to be gauged. The initial parameters of the problem were set as follows:

	ALTITUDE(FT)/RADIUS(NM)			VELOCITY(MPH)	INITIAL POSITION
AIRCRAFT 1	0	/	0	.0	.0
AIRCRAFT 2	24000	/	190.2	160.0	80.0
AIRCRAFT R	24000	/	190.2	160.0	.0

DISTANCE TO BORDER IS 36.0 MILES

IF SPECIFIED, TARGET CO-ORDS ARE X = 120.0, Y = 160.0

TOTAL AIR TIME IS 300 MINUTES

TURNING POINTS ARE X = 0.0 AND X = 240.0

To eliminate a great deal of unneeded complexity from the problem only two aircraft are used. Two aircraft are sufficient to provide the necessary elements of the problem and to permit the analysis of airborne DF.

1. The Effect of Signal Duration on a Two Aircraft Fix

The signal duration bears greatly on the ability of two aircraft (or more) to fix a given target. Table III shows the effect of several different duration signals on the ability of two aircraft to each execute an LOB on a known target. The Table shows the percentage of time a fix could be made with cuts by two aircraft staggered in time.

Most apparent from the Table is the nearly linear improvement of in fix probability as the target signal duration increases. Notably the chances of getting cuts from two aircraft on the target are 20 percent greater if the signal duration is 10 minutes rather than one minute.

2. The Effect of Target Position on Fixing Success

The position of the target emitters in the search area can have a significant affect on their probability of detection. To find out how significantly the several sets of runs were made with the parameters of several mission scenerios. Table IV shows the statistical results using the scenerio and parameters of Section C1. The target position verses the three statistical outputs of the target mode section of the computer model are given.

The meaning of this tabulated data is subject to many interpretations, but most simply it conveys the fact that targets are located around the X and Y co-ordinates shown will have varying probabilities of being acquired and fixed. For example, in this scenerio the targets close to the end points of the track or distant from the track have the least chance of being fixed.

After the study of many such sets of data it was found that the probability distribution of this tabulated data was not wholly unique. It appeared that two aircraft traversing the entire permissible track would yield this type of distribution. The parameters of this scenerio, however, seem particularly well chosen when compared to other possibilities. That is not to imply that these parameters are at all optimum or that they give a general solution. It does, however, illustrate that judgments can be made as to the best solution if alternatives are presented, as can be done iteratively with the computer model.

D. OPTIMIZATION OF AIRBORNE DF FLIGHT PATTERNS

As was stated earlier, the primary purpose of studying individual parameters and their effects if the accumulation of data base from which techniques can be derived for obtaining optimum airborne DF flight patterns. In consonance with this experimentation was begun with the computer model.

It was soon evident that the number of parameters involved did not allow ready computerization of the total optimization process. Further, it was found that trade-off situations occurred in optimization that required value judgments. This all meant that the process of optimization would have to be guided to a solution. Fortunately, interactive graphics is an effective tool where solutions can only be found through positive operator control. The computer model, then, would serve as a means of reading solutions through iteration cycles involving operator inputs, machine computation, and data display.

The use of the iterative technique proved successful in determining efficient flight patterns for airborne DF missions. To illustrate the means by which a solution is determined, an example is offered with the following initial parameters inputed to the computer model:

	ALTITUDE(FT)/RADIUS(NM)	VELOCITY(MPH)	INITIAL POSITION
AIRCRAFT 1	0 / .0	.0	.0
AIRCRAFT 2	24000 / 190.2	160.0	70.0
AIRCRAFT R	24000 / 190.2	160.0	.0

DISTANCE TO BORDER IS 36.0 MILES

IF SPECIFIED, TARGET CO-ORDS ARE X = 50.0, Y = 105.0*

TOTAL AIR TIME IS 300 MINUTES

TURNING POINTS ARE X = 0.0 AND X = 240.0

VELOCITY, INITIAL POSITION, AND TURNING POINTS ARE ALL ALLOWED VARIABLES

* Unused information in search mode

Also, the statistical data output of the computer model was set up to display the following statistics:

SEARCH MODE

PERCENT OF TIME

1. F.O.V. INTERSECT APERATURE GREATER THAN 20 DEG.
2. COMMON AREA GREATER THAN 30.0 PCT OF SEARCH AREA

PERCENT OF SEARCH AREA COVERED

TARGET MODE

PERCENT OF TIME

1. TARGET IN RANGE OF TWO A/C
2. TWO A/C APERATURE GREATER THAN 20 DEG.
3. VIEW OF TARGET WITHIN 5.0 MIN. OF TWO A/C

This example will be used to show three types of solutions. The first solution is for the best fix of the primary target only. The second solution is for the best flight pattern to search for targets in the area along the aircraft track and across the border. Finally, the third solution is a mix of the first two,in that it is for the coverage of the primary target but not at the expense of the search for new targets.

Computing the first solution is quite determistic and straight forward. Since only the coverage of the target must be insured just two factors must be considered, distance to target and aperature. To get maximum aperature the first aircraft must orbit around the origin end of the aircraft track and the second orbit where it maintains the target in view and contributes to as large an aperature as possible. If the model program is used to increment the second along the aircraft track the optimum position can be taken off the graphics displays of aperature and possibility of fix or the hard copy print out. In this case it will be found that under "radar horizon" conditions the best aperature is 81.9 degrees and occurs with the first aircraft at X = 0.0 and the second at X = 208.0.

Determining the best search pattern to fly requires very active use of investigative experience and the iterative process. Unlike the first case the aircraft must constantly

travel along the border if most of the area is to be inspected simultaneously by two aircraft. Since short duration signals are considered the most likely, only the overlapping coverage of areas counts toward productivity.

In beginning a solution to the search problem an estimate of the best solution must be made to establish a starting point. Usually this estimation is based on the maintenance of large overlapping areas covering the extent of the search area and keeping proper aircraft distance for good aperatures in the area of overlapping coverage. To accomplish the above to any degree means that certain practices are followed.

One practice requires that the aircraft fly at the same or nearly the same altitude whenever possible. This is mainly for economy reasons. That is, if one aircraft flys much higher than the other it has areas in view which the lower aircraft will never see, thus no simultaneous coverage. It may be argued, however, that the overlapping area with the lower one is increased. However, if the energy is to be expended to fly one higher why not fly both equally high and get a large improvement with no areas in the search area beyond overlapping coverage.

Another practice requires that the aircraft traverse the entire permissible aircraft track, preferably at a fixed distance apart. It is necessary for the aircraft to travel the entire track if there is to be any possibility of the whole search area receiving overlapping coverage, if even just momentarily (ends of the search area usually suffer even

in optimum solutions). Ideally, if both aircraft flew very close together a large percentage of the search area would be seen at any one time and all parts of the search area could be viewed at least once given sufficient travel time. However, this is where the second part of the practice being discussed comes in. If thereis to be any aperature at all on emitters in the overlapping area regions there must be good aircraft separation. Unfortunately, good aperatures and large overlapping area coverage are in opposition to one another. Usually a compromise must be made based on the minimum aperature necessary to get a good fix and the desired overlapping area to be covered. In the end a simple estimation following this practice helps give a good start to the interation process. However, it should be noted that with this practice and others exceptions do occur depending on the conditions imposed upon the problem.

With the above practices as a guide the iteration process was begun. A couple initial runs were made to find a good interval between aircraft and adjustments in the parameters started from there. Table V shows the iterative sets of statistical data computed by the model program. The first three rows of the sets apply to the optimization of search patterns. These statistics allow judgments to be made quickly on the merits of the parameters selected. If the results are unsatisfactory the parameters can be adjusted and their effects observed again. The sets of statistics in Table V represent this adjustment and readjustment process (some intermediate sets have been deleted).

Except for perhaps set one, set seven and eleven are clearly the best in terms of statistics and therefore represents the best flight parameters examined. Set one has been eliminated because although it maintains good aperatures it only manages to see 30 percent of the search area 43 percent of the time and only gives overlapping coverage to 60 percent of the total search area. These two factors override what little advantage set one has over set seven in attainable aperature. Sets eight through twelve represent additional iterations to find better parameters, but with success only in set eleven. The parameters of set seven, or set eleven then, would be selected if an airborne DF mission was desired for the purpose of an area search along the permissible aircraft track.

The third solution for the best target and search area coverage is the most complicated and subjective solution of all. However, it's also the most common solution required. In this example only one primary target is present in the search area. This makes the problem considerably less subjective and more illustrative than multiple target situations.

Table V also gives the statistical data sets used to find the optimum solution. For this problem all six statistics must be considered and the best set of six chosen as representative of the best set of parameters. Best in this problem will denote good coverage of the total search area plus good target coverage, with trade-offs for excellence

in either coverage. The practices of the previous solution for the best search pattern also apply here when also consistent with good target coverage.

The initial estimate of the best solution for this problem dictated the same initial parameters as the search area problem. The iterative set of statistics for that problem also led to the solution of the problem at hand. This was not unexpected since by their nature the aperature and coverage consideration for the search mode can also be conducive to good aperatures and coverage in the target mode.

The iteration process in this problem determined that set twelve represented the best set of parameters. Since the selection is not totally obvious it must be clarified slightly. First, set eight is clearly better than sets two through six and set eight. Secondly, it is better than one, nine and ten because of their considerably poorer search mode statistics (1 to 3) which are not compensated for by their only slightly better target mode statistics (4 to 6). Thirdly, twelve is better than sets seven and eleven because a small trade off in statistic one gives set twelve markedly better performance in the target mode statistics than those two other sets can offer. Therefore, twelve is selected as representing the best choice of parameters. Appendix D gives the parameter, statistical data, and flight data for that solution.

The arguments for the best parameters yielding the optimum solution in this problem are fairly clear, being based on the

importance of total or near total search area coverage and good target coverage. The problem was subjective in that both were impossible to maximize at one time so trade-offs occurred to get the most improvement in one area for the least sacrifice in another. Under other problem conditions the results may have been different. For example, if target coverage had a higher priority than search area coverage set ten would probably have been more acceptable than set twelve.

As with this example, other work has shown that in all but the most elementary situations good solutions are the result of compromises. The subjective task at hand when the compromises must be evaluated is recognized as being the most difficult phase of the solution process, a phase which cannot be computerized. However, that part of the process that was automated through the computer model proved to be efficient in pursuing a solution to the point where subjective intervention was required.

E. SCALING SOLUTIONS

Once an optimum or near optimum solution was found for a set of circumstances it seemed reasonable that this solution should be able to be extended in a scaled form to similar situations, where only the distance to the EM horizon differs. To test the feasibility of such scaling, a series of scalings were performed on a set of parameters and the computer model used to evaluate the results. An example of this scaling and a comparison of the statistical results of the two modelled flights are shown in Table VI. The results

are typical in that at no time in the testing was a scaled solution off more than one percent from the original when statistics were compared (error due to incremental fineness of model). Overlapping field of view areas were also found to conform to the scaling, being related by the square of the scaling factor.

V. CONCLUSIONS

The ultimate result of this study shows that an airborne DF system may be optimized based on geometric and signal duration considerations. However, the process of optimization was not found to be totally straightforward since in all but the simplest cases subjective judgments and compromises were required in the final steps of solution.

It was also found that the practices developed during the study of flight and target parameters could accelerate the convergence of computer derived solutions. These same practices without the use of a computer can also be valuable in deriving good (though not optimum) estimates of the best solution. The practices can be summarized as follows for two aircraft:

1. It is most efficient to fly aircraft as near as possible to the same altitude.
2. If the density of targets in the search area can be considered uniform then each aircraft must traverse the entire permissible aircraft track in order for a large degree of coverage to be attained. During most of the flight the aircraft should maintain a constant spacing, sufficiently wide for good aperatures at a reasonable distance.
3. Normally, self aperature should not be relied upon as a primary means of fixing short duration emitters.

4. If searching as well as maintaining coverage on a specific target first ensure spacing of aircraft is such that a satisfactory aperature will be maintained on the target during a large portion of the flight.
5. Specific target coverage and search coverage are generally opposed and require different solutions. Each must be optimized with particular weights if both search and target coverage are desired.
6. Three aircraft can improve median area coverage by much more than 30 percent over two aircraft coverage. Where resources permit this nonlinear relationship between area coverage and aircraft can provide the basis for greatly improved coverage.

Reviewing the results of this study it appears that only an initial penetration has been made of the airborne DF problem. A general problem was defined as the subject of study in the beginning, and a general method of solution advanced in the end. However, the process of evaluating airborne DF has been somewhat weighted down by the generalities of the problem and its proposed solution. Further work needs to be done in identifying the bounds on the problem and in investigating the feasibility of a fully automated technique for solving deployment problems. These two tasks may be complementary in that narrower bounds may result in the elimination of the need for subjective decisions in the solution process which presently thwart full automation. Beyond this, the need still exists for work that will lead

to recommendations for the design of future airborne DF systems. Significant improvement can be expected in the system for a relatively modest investment in research.

APPENDIX A

PROGRAM USE

The use of the program will be described as it is run on the Naval Postgraduate School XDS 9300 computer and Adage/10 graphics terminal. The program is 14,000 words long and uses three external subroutines; specifically GINPUT, FNS and VPLOT. GINPUT permits namelist inputs through the teletypewriter, FNS allows use of the graphics terminal function switches and VPLOT permits graph outputs to the line printer. The model program is loaded into the XDS 9300 by means of punched cards and punched tape (for subroutines) or loaded directly from magnetic tape. When the program has been loaded and is ready for exectuion the Computer's teletypewriter will print out:

TYPE IDEV=1*C/R FOR AGT-1 OR IDEV=2*C/R FOR AGT-2

Before proceeding past this point, the graphics terminal is readied by loading and executing the program MAD or GBOAT located on a display terminal disk pack. Then, as instructed the number of the graphics terminal just readied is typed in on the XDS 9300 teletypewriter. This causes the data cards to be read in from the card reader (see Fig. 8 for format). These cards contain the initial conditions and parameters of the airborne system. From this point on in the program all control is at the display terminal. Thus, all input and all

output will be initiated from the terminal. Figure 9 is a flow chart illustrating the possible choices of graphic and hardcopy display.

The first display at the graphics terminal is the Statistical Data page (see Fig. 10). Six percentages are shown which act as figures of merit for the DF flight just generated. A record of this page and the input parameter is kept at the line printer. This page is exited by pressing the teletypewriter carriage return key.

The second display at the terminal is the Graph Selection List page, Fig. 11. Three options are shown. The first is time versus area plot -- selected by pressing function switch 13. The second is time versus the aperature between aircraft two and the reference aircraft (R designates reference aircraft) -- selected by pressing function switch 14. The third option is the time versus the possibility of a fix on the target by any two aircraft -- selected by pressing function switch 15. A note at the bottom of the display page indicates that after selecting an option and receiving the proper graph the graph option list page can be returned by pressing function switch 10. This return can only be initiated from the graphics page shown as the GRAPH DISPLAY block in Fig. 9.

After the selection of a graph the Adage console displays a page like Fig. 12, 13, or 14 corresponding to function switches 13, 14, or 15, respectively. The page consists of a table of parameters, a graph and an option.

The table of parameters lists the values of the inputs to the program model from which the data curve was generated.

The graph section of the screen consists of a border along which the axes are labelled, the data curve and sometimes a set of zero axis. The data curve is scaled using the maximum and minimum values of the data plotted. This allows the best use of the viewing area, but consequently the zero axis are sometimes out of view off-screen with the scale being used.

Much like the options on the graph selection page, the items in the option box give program options and the function switches necessary to execute them. The Fig. 9 GRAPH DISPLAY block shows that there are three options available at the graph display. The first option, branch to block 3 of Fig. 9, turns the cursor on and displays its X-Y coordinates at the right-top of the screen (Fig. 15). The position of aircraft two at that point in time is also given. It will be noted that a new list of options has been placed in the option box. The first and second of these options give the function switches necessary to move the cursor forward or back along the curve. The third option turns the cursor off and erases the readout at the right-top of the screen. The program is now back at the GRAPH DISPLAY block 2 of Fig. 9, and the option box reflects this.

Option two initiates hardcopy output on the line printer. The Computer Output section of this paper provides examples of this. All the information available at the graphics terminal can be saved this way for future reference.

The hardcopy graphs actually provide more information than their graphics terminal counterparts, because of the increased space and symbology available on the printout version. The first graph, Time versus Overlapping Area (sq nmi), displays the same information as does the graphics terminal Area Display. The second graph, Time versus Plane Position, has no graphics terminal counterpart and displays all three aircraft positions during the flight. The third graph, Time versus Two Plane Aperature, is much like the graphics terminal Aperature (2-R) display, except aperatures of planes one and R (reference), and planes one and two are also shown. The fourth graph, Time versus Target in Range, is not unlike the graphics display Possibility Of Fix. Where the printer plot shows whether each plane is view of the target at any one moment, the graphics terminal plot just shows if any two are in view of the target simultaneously. Both graphs show a Yes response as a one (1) and a No response as a zero (0).

The program does not return to block 2 after the completion of the printout but instead branches to the Namelist Input section. This section is also the third option contained in the GRAPH DISPLAY option box. The words NAMELIST INPUT appear at the bottom left of the screen when this option has been implemented (Fig. 18).

The Namelist Input section is the vital section where the model parameters can be changed and rerun in the program. Certain program control functions can also be performed.

Table VII lists all the parameters that can be changed by a namelist input. An example of this is:

POS2 = 20.0 C/R

This changes the previous value of the initial position of aircraft 2 to +20.0 miles from a 0 reference. All parameters, except HITE, INCR, and INM are of the type specified by the convention that words starting with I J K C M or N are integers and all others are real.

Control words are listed in Table VIII along with a brief summary of their use. To expand slightly on NERR, it is used when an error in the location of the target is to be introduced into the program. Different XP and YP values indicate that not all the aircraft see the target at the same point, and therefore prevent an exact fix. Data produced thusly can be used in many facets of problem study. If the error function is not required in the problem XP2 and XP3 are set to the value of XP1, and YP2 and YP3 set to the value of YP1 by making NERR = 0.

The namelist input can be used to change the parameters of the model with the restrictions of Table IX, and allow one to pursue the consequences of parameter variance at a rapid pace. Processing data for a five hour flight at one minute intervals only takes an average of five seconds, including the graphics plot.

(For reference, Appendix D contains the computer program. Table X is a list of frequently used program variables.)

APPENDIX B

TABLES

SEPARATION IN TIME (MIN.)	SEPARATION IN N. MILES	Y COORD OF TARGET	MAXIMUM FLIGHT APERATURE
1	2.67	40	3.8
		160	1.0
5	13.3	40	18.9
		160	4.8
10	26.7	40	36.9
		160	9.5
20	53.4	40	67.5
		160	19.0

TABLE I

SELF-APERATURE DATA

NUMBER OF AIRCRAFT	RANGE OF COMMON AREAS (SQ.MI.)	APPROX. MEDIAN AREA	MED. AREA FACTOR
2	9,460 - 43,238	26,348	1
3	40,766 - 43,238	42,002	1.6

TABLE II

TWO VERSUS THREE AIRCRAFT COMMON AREA

SIGNAL DURATION (MIN)	PCT. OF TIME SIMUL. LOB'S FROM 2 A/C POSSIBLE	PCT. OF TIME LOB'S FROM 2 A/C POSSIBLE
.1	71.4*	71.6
.5	71.4+	72.4
1	71.7	74.0
2	71.7	76.3
5	71.7	83.3
10	71.7	94.0
20	71.7	100.0

* Based on 1,500 points

\+ Based on 600 points

All others based on 300 points

TABLE III

EFFECT OF SIGNAL DURATION ON TWO AIRCRAFT FIX

TARGET POSITION		TARGET MODE STATISTICS		
Y	X	1	2	3
60	0	50.0	62.0	53.3
	60	100	60.3	100.0
	120	100	79.0	100.0
	180	100	71.3	100.0
	240	67.3	67.3	70.7
120	0	35.7	84.1	37.3
	60	66.7	86.5	73.3
	120	100.00	77.0	100.0
	180	79.0	83.5	84.0
	240	54.0	79.0	57.3
180	0	5.7	0	7.3
	60	25.7	67.5	27.3
	120	19.7	100.0	26.3
	180	40.7	59.0	44.0
	240	11.3	0.0	14.7

TABLE IV

EFFECT OF TARGET POSITION ON FIXING SUCCESS

	SET 1	SET 2	SET 3	SET 4
POSITION 2/R	70/0	70/0	70/0	70/0
VELOCITY 2/R	160/0	160/160	140/140	160/160
TRN. PTS 2*	0/240	0/240	0/240	40/240
STATISTIC				
1	83.3	75.0	74.3	75.0
2	43.3	100.0	100.0	76.3
3	60.0	88.0	88.0	82.0
4	84.0	68.7	71.7	68.7
5	74.0	51.3	55.0	47.7
6	85.3	71.3	73.7	71.3

	SET 5	SET 6	SET 7	SET 8
POSITION 2/R	70/0	70/0	70/0	70/0
VELOCITY 2/R	160/160	170/170	180/180	200/200
TRN. PTS 2	40/240	0/240	0/240	0/240
STATISTIC				
1	75.0	76.7	77.3	73.3
2	88.7	100.0	100.0	100.0
3	80.0	88.0	88.0	88.0
4	78.7	70.3	72.0	74.7
5	55.7	54.3	56.7	57.3
6	81.3	73.0	74.7	77.3

	SET 9	SET 10	SET 11	SET 12
POSITION 2/R	0/0	240/0	170/240	170/240
VELOCITY 2/R	160/0	-160/0	-180/-180	-170/-170
TRN. PTS 2	0/240	0/240	0/240	0/240
STATISTIC				
1	75.3	67.3	77.3	76.7
2	47.7	57.3	100.0	100.0
3	61.0	61.0	88.0	88.0
4	84.7	88.3	78.0	81.3
5	70.0	69.0	59.3	62.3
6	86.0	89.7	80.0	83.3

* Turning points for the reference aircraft fixed at X = 0 and
X = 240

TABLE V

EXAMPLE SETS OF ITERATIVE STATISTICS
USED FOR PARAMETER OPTIMIZATION

(a) ORIGINAL AND SCALED PARAMETERS

PARAMETER	A/C 2		A/C R	
	ORIGINAL	SCALED*	ORIGINAL	SCALED
F. O. V. RADIUS	190.2	133.1	190.2	133.1
VELOCITY	160.0	112.0	160.0	112.0
INITIAL POSITION	80.0	56.0	0.0	0.0
TURNING POINTS	0/240	0/168	0/240	0/168

PARAMETER	ORIGINAL	SCALED
DISTANCE TO BORDER	36.0	23.2
TARGET COORDS	X = 120.0 Y = 180.0	84.0 126.0
AIR TIME	300	300

* Scaling factor of 0.7

(b) STATISTICAL DATA COMPARED BEFORE AND AFTER SCALING

	ORIGINAL	SCALED
PERCENTAGE OF TIME		
1. F.O.V. INTERSECT APERATURE GREATER THAN 20 DEG. ------------------------------	75.0	75.0
2. COMMON AREA GREATER THAN 30.0 PCT. OF SEARCH AREA ------------------------------	100.0	100.0
PERCENT OF SEARCH AREA COVERED -------------------	86.0	86.0
PERCENTAGE OF TIME		
1. TARGET IN RANGE OF TWO A/C -----------------	19.7	19.7
2. TWO A/C APERATURE GREATER THAN 20 DEG. ------	100.0	100.0
3. VIEW OF TARGET WITHIN 5.0 MIN. OF TWO A/C ---	26.3	26.3

TABLE VI

EXAMPLE OF SCALING

TABLE VII

INPUT PARAMETERS

DB	average distance to border from aircraft track
HITE1	altitude of aircraft one (integer number)
HITE2	altitude of aircraft two (integer number)
HITER	altitude of aircraft three* (integer number)
IANG	statistical aperature parameter - target mode
IANGX	statistical aperature parameter - search mode
INCR	time increment in minutes (real number)
INM	statistical time parameter - target mode (real number)
POS1	initial position of aircraft one
POS2	initial position of aircraft two
POSR	initial position of aircraft three
PSA	statistical area parameter - search mode
R1	radius of the circle of observation for aircraft one
R2	radius of the circle of observation for aircraft two
RR	radius of the circle of observation for aircraft three
TIME	total flight time on track
TM1	lowest value turning point for aircraft one
TM2	lowest value turning point for aircraft two
TMR	lowest value turning point for aircraft three
TP1	highest value turning point for aircraft one
TP2	highest value turning point for aircraft two
TPR	highest value turning point for aircraft three

*Aircraft three has been designated the reference (R) aircraft.

VEL1	velocity of aircraft one
VEL2	velocity of aircraft two
VELR	velocity of aircraft three
XP1	x coordinate of target as seen by aircraft one
XP2	x coordinate of target as seen by aircraft two
XP3	x coordinate of target as seen by aircraft three
YP1	y coodinate of target as seen by aircraft one
YP2	y coordinate of target as seen by aircraft two
YP3	y coordinate of target as seen by aircraft three

TABLE VIII

CONTROL WORDS

IX	Input IX=1 into namelist to exit from program.
NERR	Input NERR=1 into namelist to enable individual assignment of XP1, XP2, XP3, YP1, YP2, YP3 values. If not specified NERR=0 and XP3=XP2+XP1 and YP3=YP2=YP1.
IALL	Input IALL=1 into namelist to print all M data sets when FNS 11 is depressed (50 sets are normally output).

TABLE IX

INPUT LIMITATIONS

Parameter	Must be less than:
HITE_	100,000 feet
INCR	1,000 minutes
IANG	180 degrees
IANGX	180 degrees
INM	1,000 minutes
POS_	1,000 miles
PSA	100.0 percent
R_	1,000 miles
TM_	1,000 miles
TP_	1,000 miles
TIME	1,000 minutes
VEL_	1,000 miles per hour
XP_	1,000 miles
YP_	1,000 miles

TABLE X

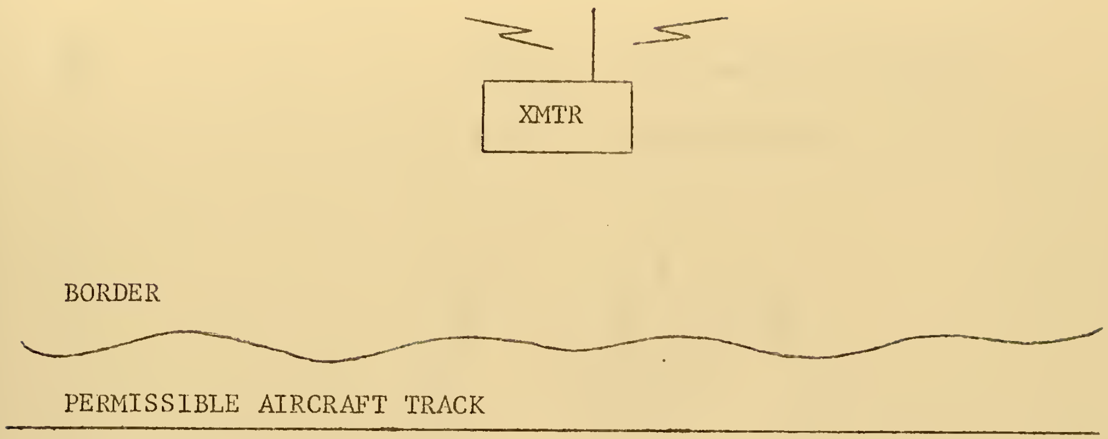
FREQUENTLY USED PROGRAM VARIABLES

AP(I,1)	aperature between aircraft one and two
AP(I,2)	aperature between aircraft one and three
AP(I,3)	aperature between aircraft two and three*
DST(I,1)	distance to target from aircraft one
DST(I,2)	distance to target from aircraft two
DST(I,3)	distance to target from aircraft three
M	time divided by INCR
TRNPTM	lowest value turning point on aircraft track
TRNPTP	largest value turning point on aircraft track

APPENDIX C

FIGURES

a) PROBLEM



b) MODEL FOR A/C COVERAGE

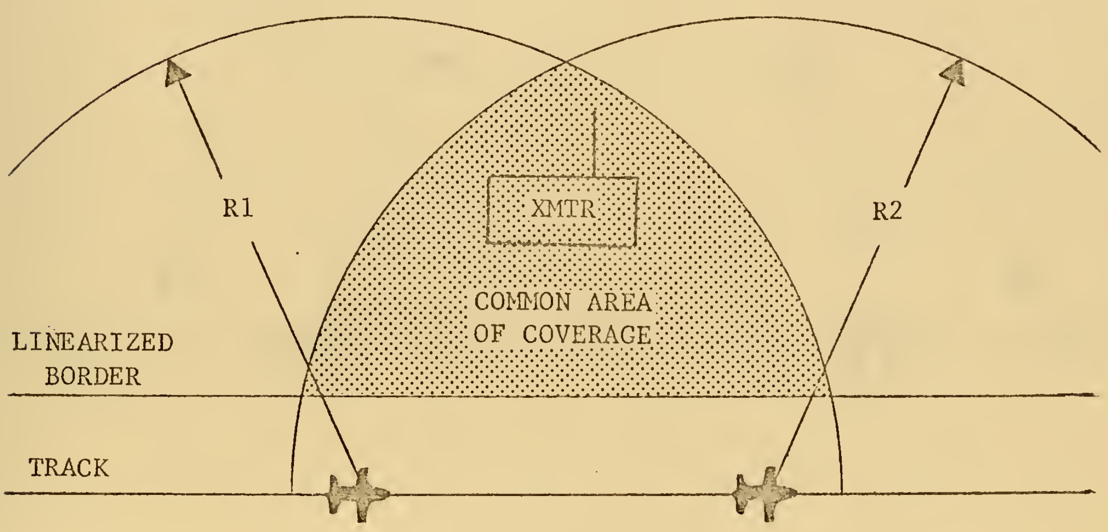


FIGURE 1

PROBLEM AND COVERAGE MODEL

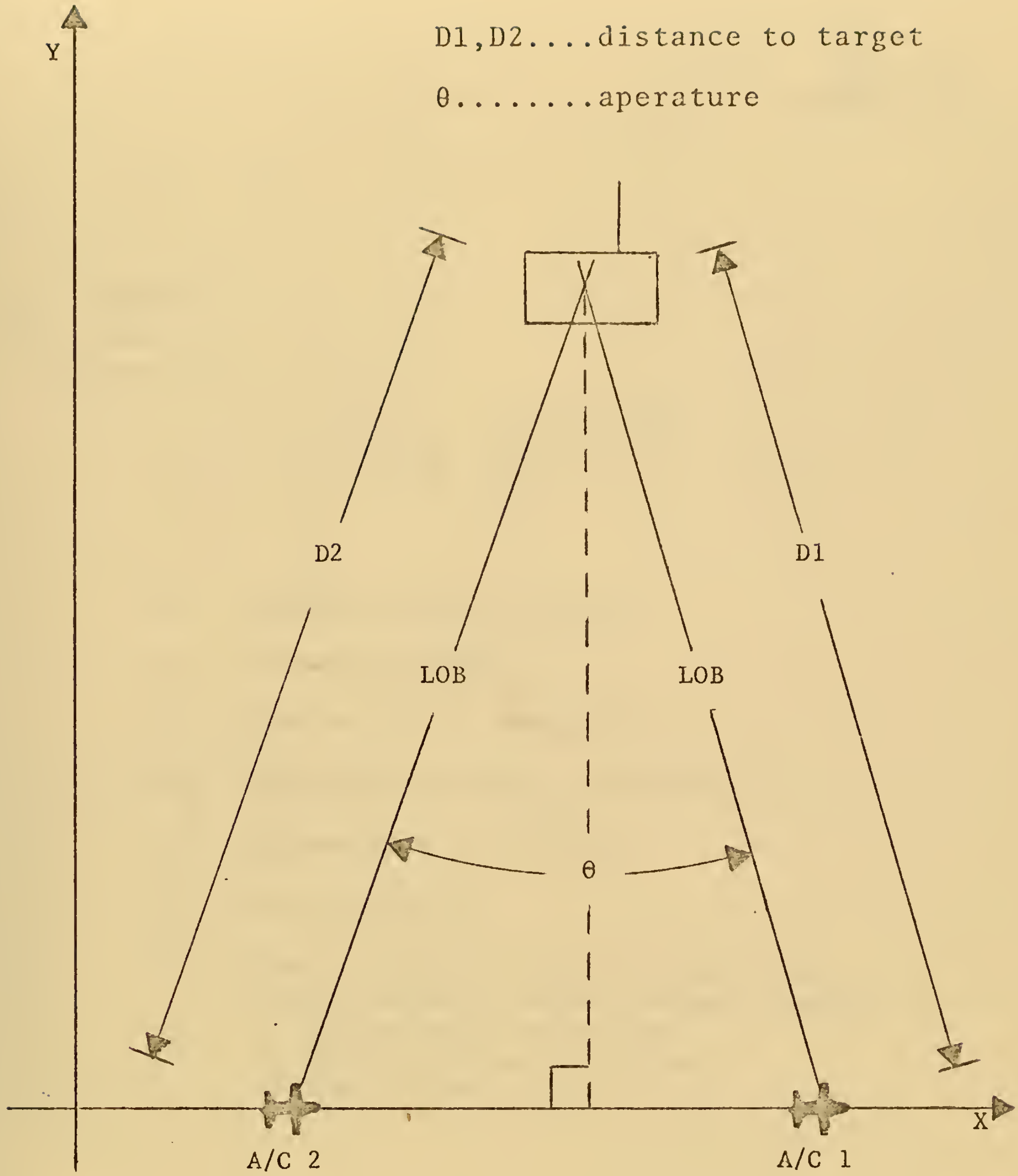
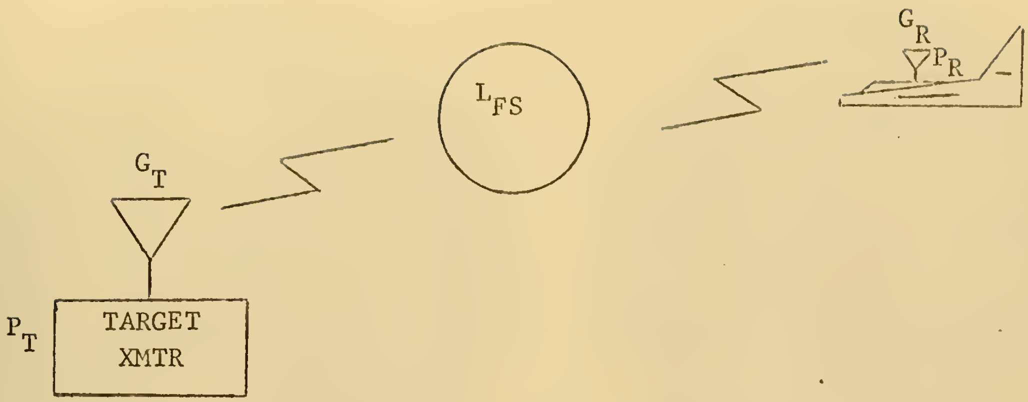


FIGURE 2

APERATURE AND DISTANCE TO TARGET MODEL



$$R = \frac{\lambda}{4\pi}\left[\frac{P_T G_T G_R\ X}{P_R}\right]^{\frac{1}{2}}$$

R = Maximum intercept distance

P_T = Transmitter power

G_T = Antenna gain at transmitter

L_{FS} = Free space loss ($L_{FS} = 16\pi^2 R^2/\lambda^2$)

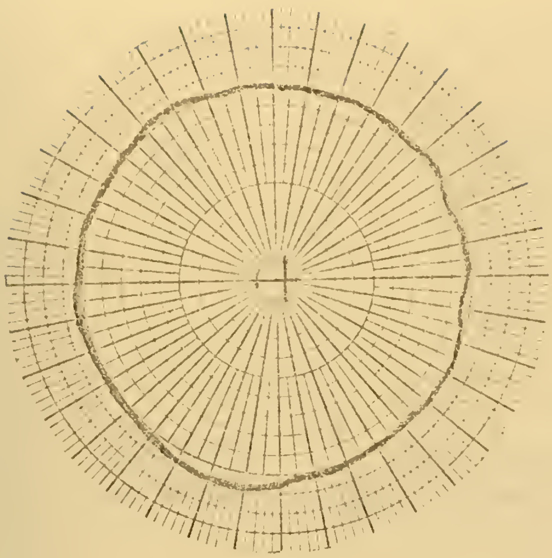
G_R = Antenna gain at receiver

P_R = Power receiver

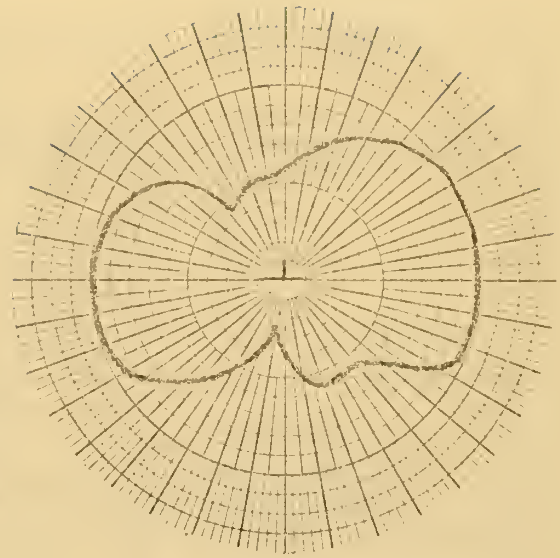
X = Factor composed of contributing losses
a) Environmental losses (weather, terrain...)
b) Antenna polarization loss
c) Internal system attenuation
d) Other variant losses

FIGURE 3

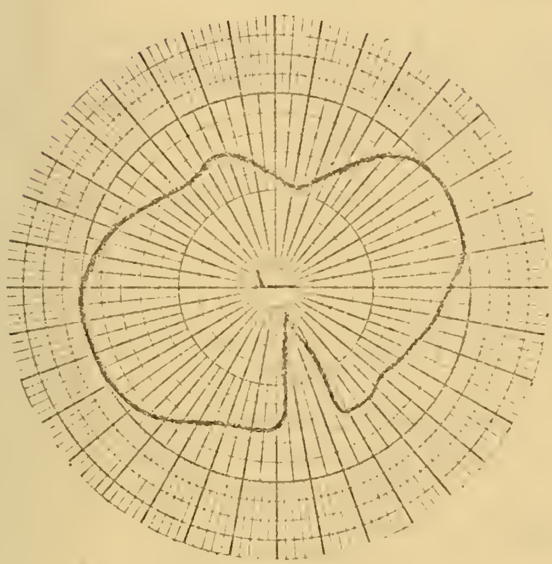
LINK MODEL



a) Horizontal Plane



b) Frontal Plane



c) Side Plane

FIGURE 4

ANTENNA PATTERNS

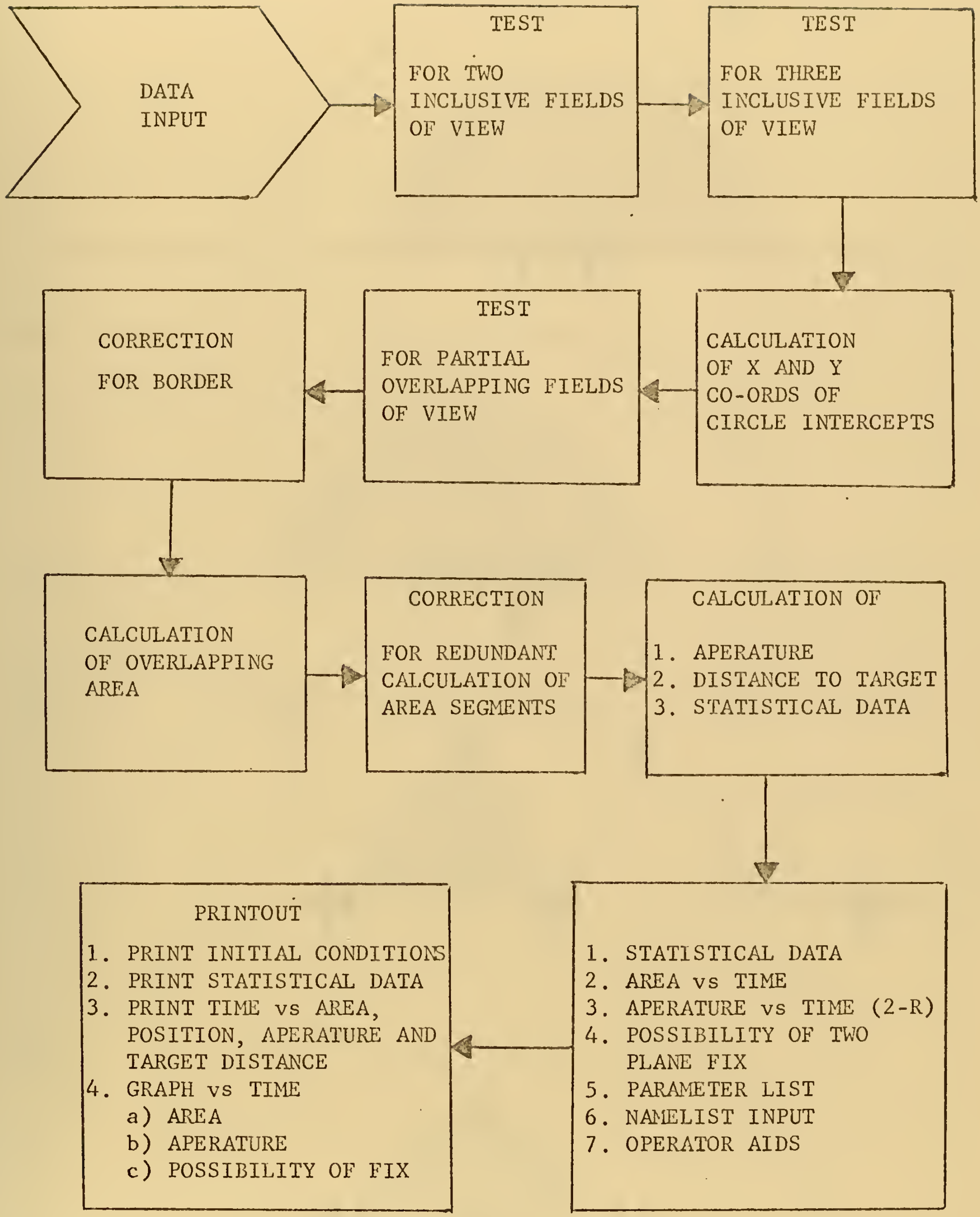


FIGURE 5

SECTIONAL PROGRAM FLOWCHART

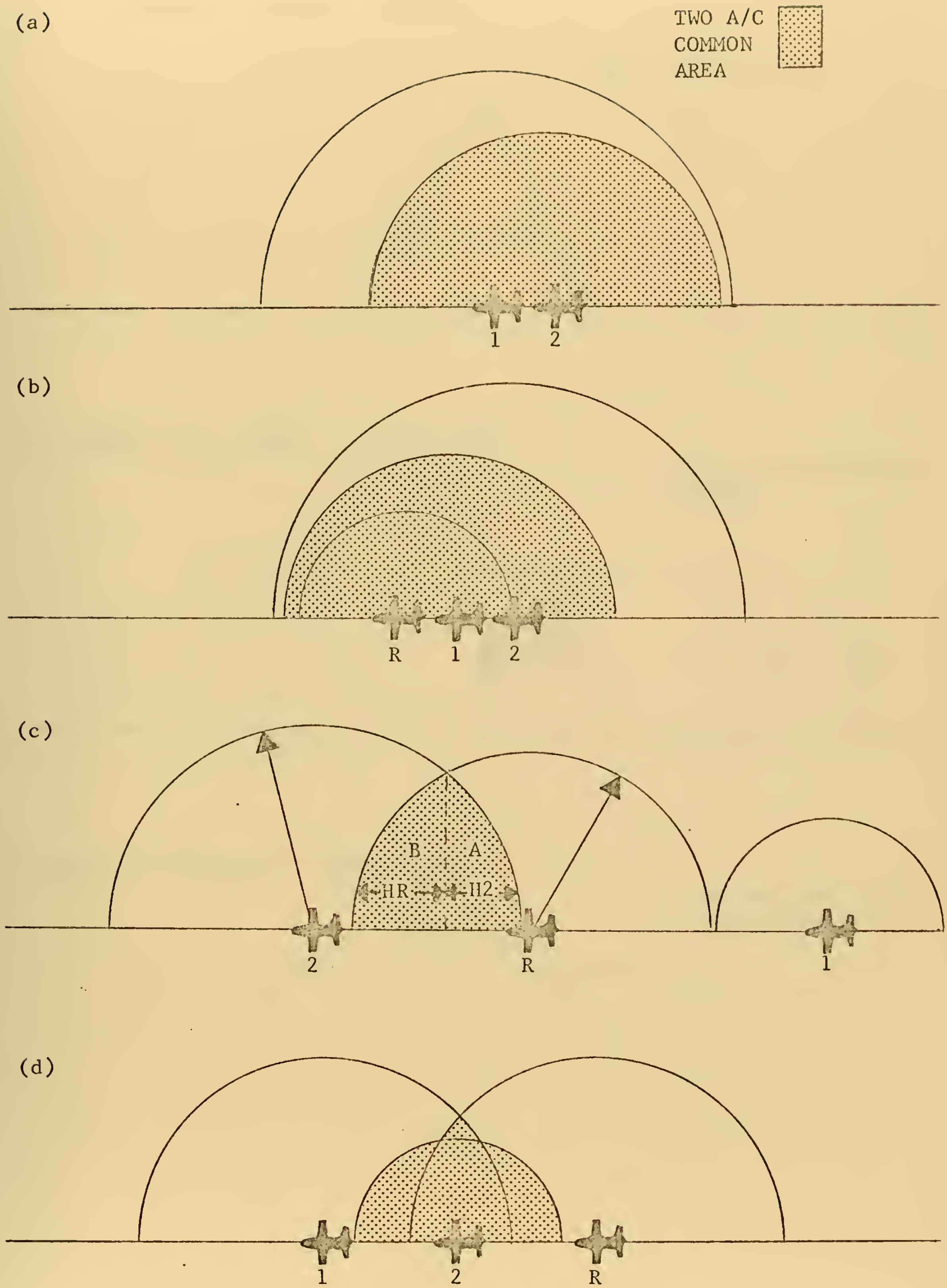


FIGURE 6

REPRESENTATIVE COMMON FIELD-OF-VIEW SITUATIONS

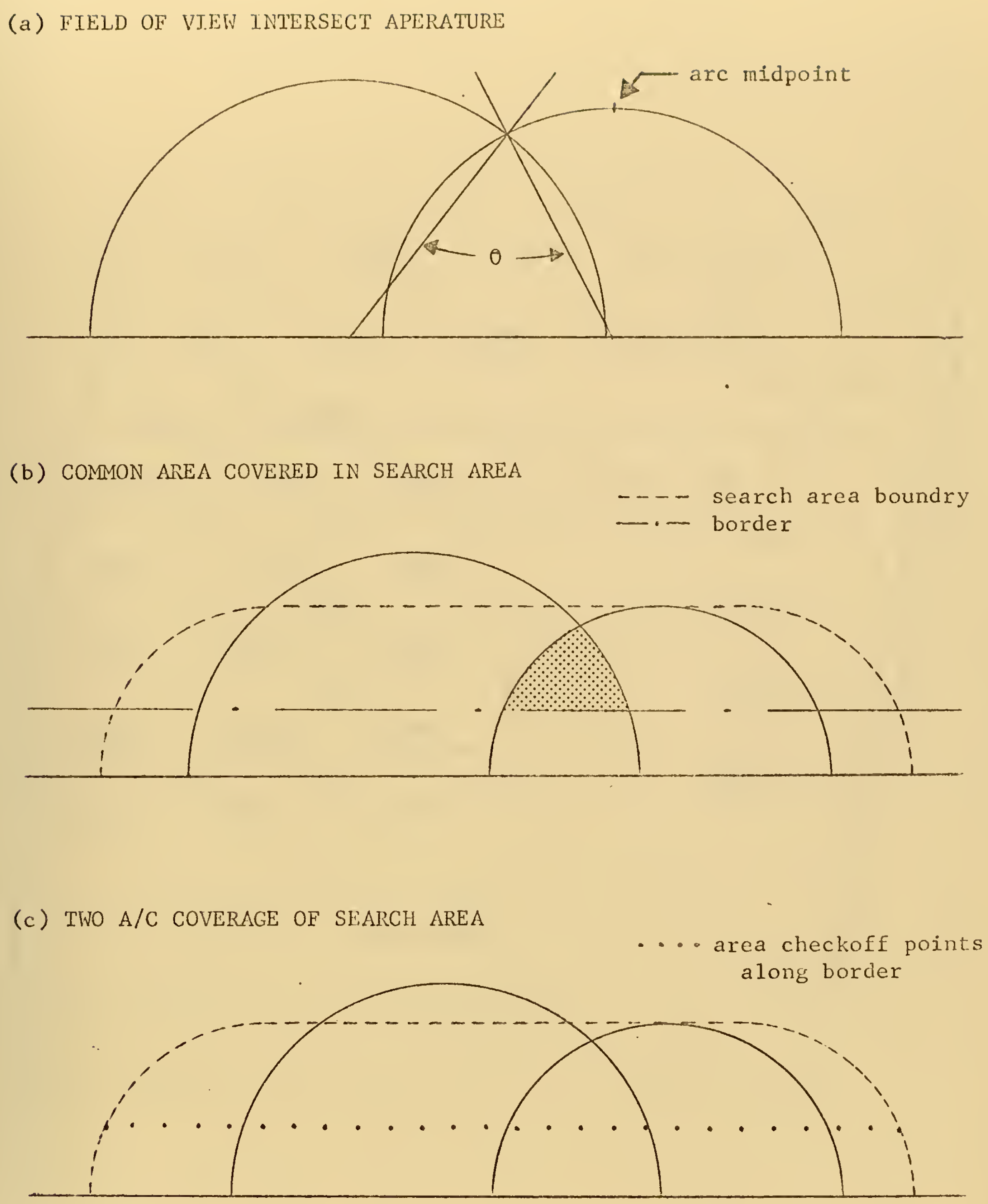


FIGURE 7

STATISTICAL MODEL FOR SEARCH MODE OPERATION

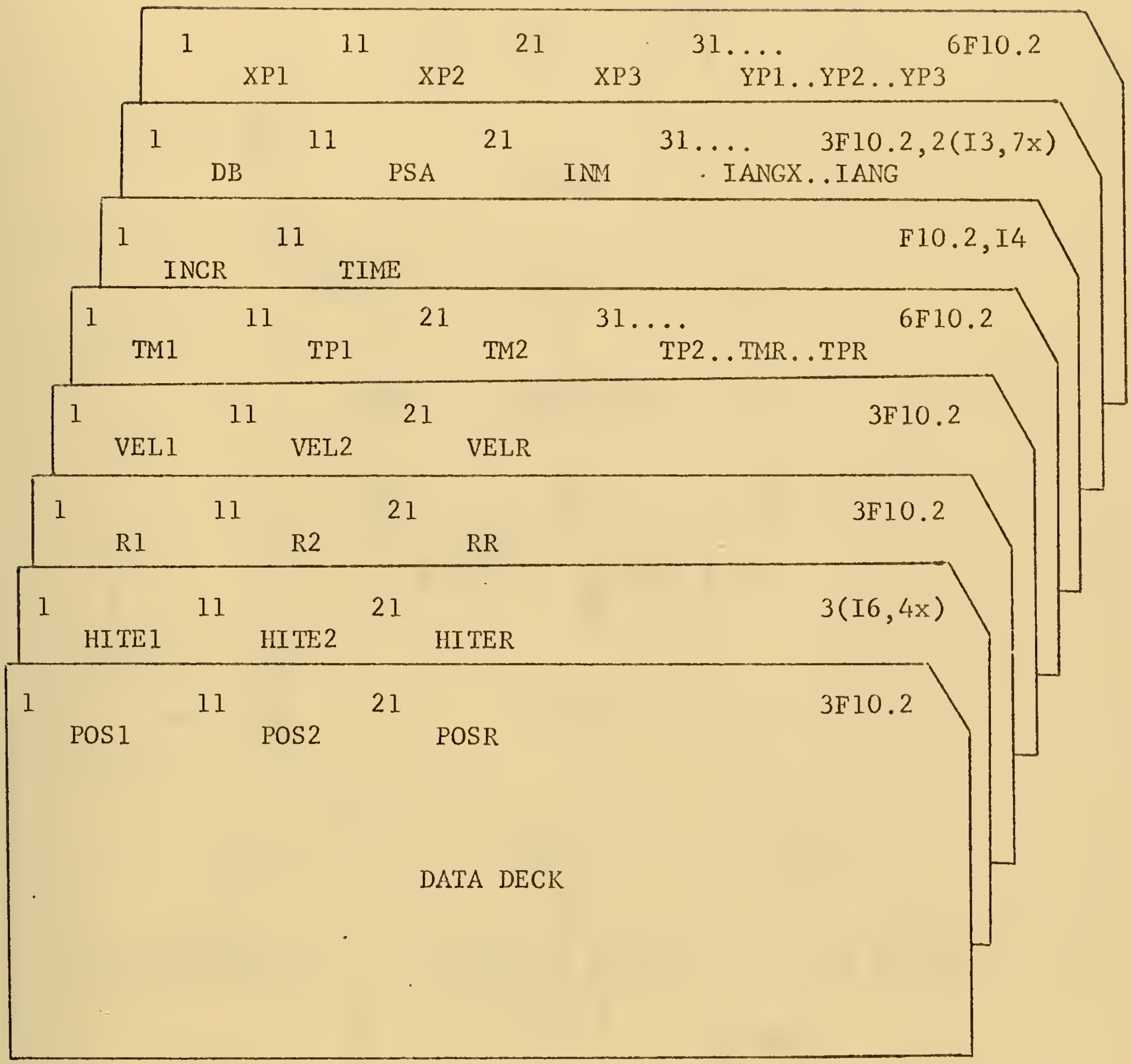


FIGURE 8

DATA DECK FOR FIRST RUN INITIALIZATION

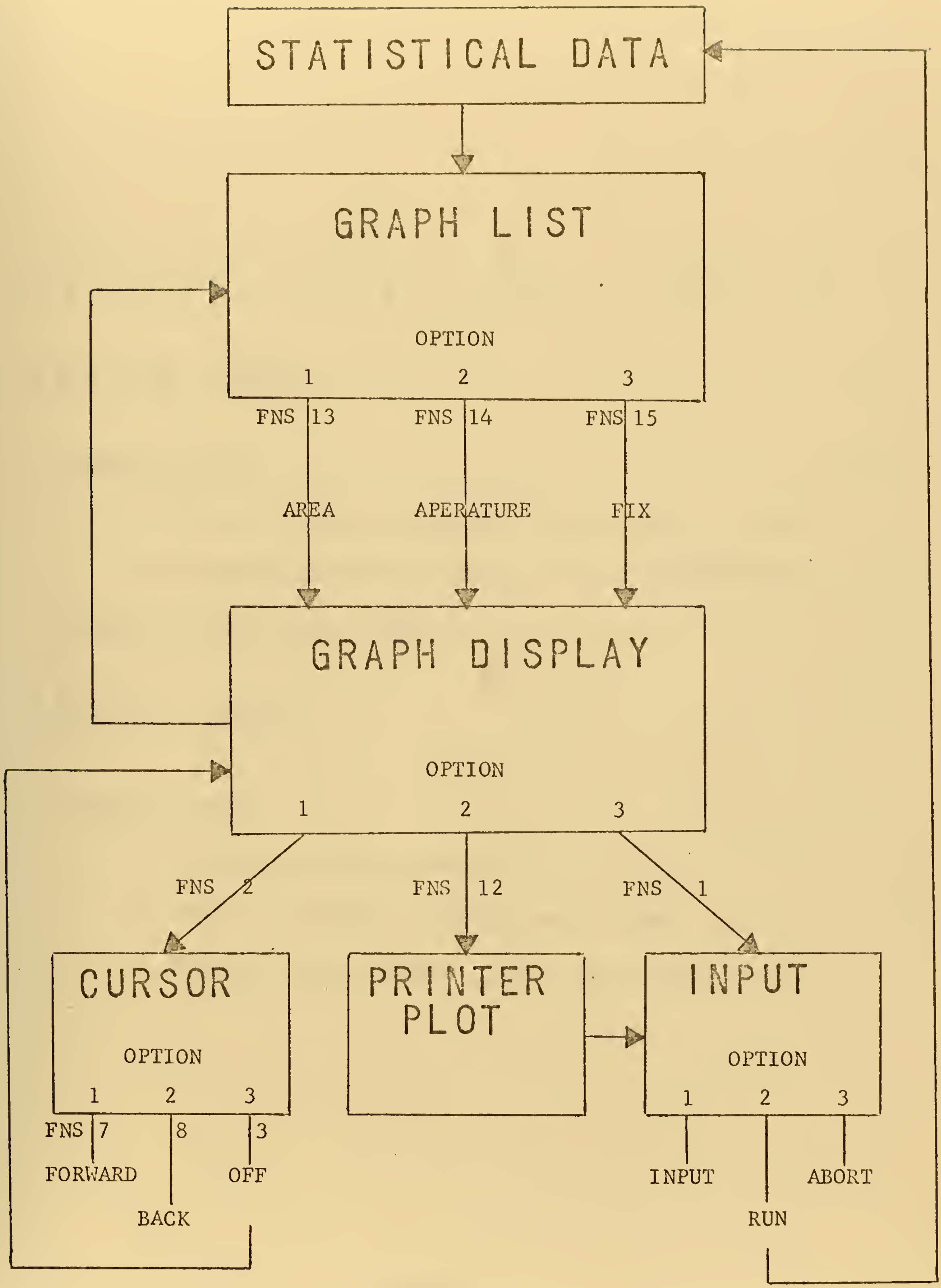


FIGURE 9

FLOW CHART OF GRAPHICS DISPLAY CONTROL FUNCTIONS

STATISTICAL DATA

SEARCH MODE

PERCENT OF TIME

1. F.O.V. INTERSECT APERATURE GREATER THAN ___ DEG. .. ___._
2. COMMON AREA GREATER THAN __._ PCT. OF SEARCH AREA . ___._

PERCENT OF SEARCH AREA COVERED .... ___._

TARGET MODE

PERCENT OF TIME

1. TARGET IN RANGE OF TWO A/C .... ___._
2. TWO A/C APERATURE GREATER THAN ___ DEG. .... ___._
3. VIEW OF TARGET WITHIN __._ MIN. OF TWO A/C .... ___._

FIGURE 10

STATISTICAL DATA PAGE

OPTIONS: 1.AREA DISPLAY..FNS 13

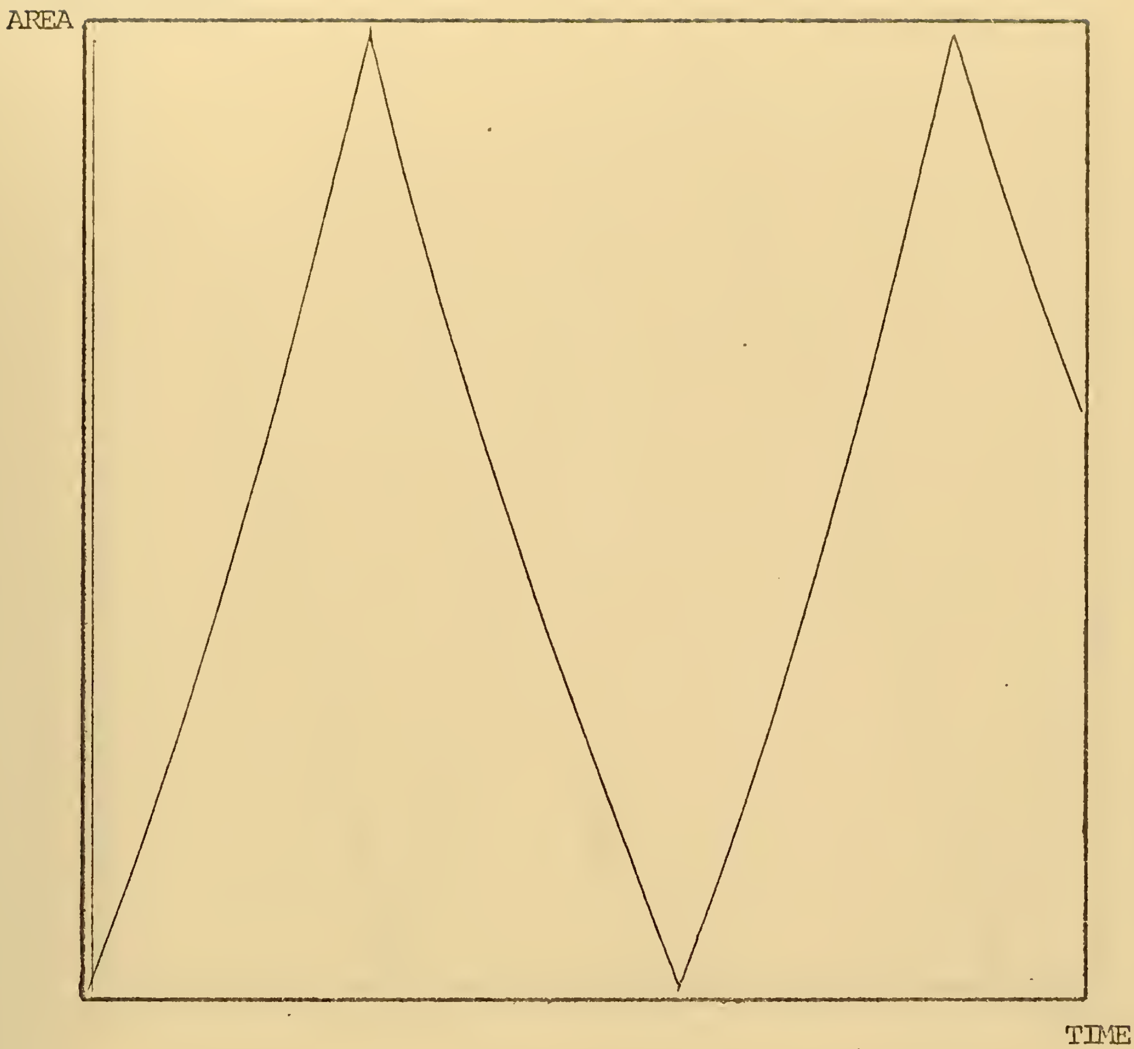
2.APERATURE(2-R)..FNS 14

3.POSSIBILITY OF FIX..FNS 15

FNS 10 WILL RETURN PROGRAM TO THIS LIST

FIGURE 11

GRAPH SELECTION LIST PAGE



HITE1= 0 HITE2= 24500 HITER= 24500 DB= 40.0

R1= .0 R2=190.2 RR=190.2 TRNPTM= .0 TRNPTP= 240.0

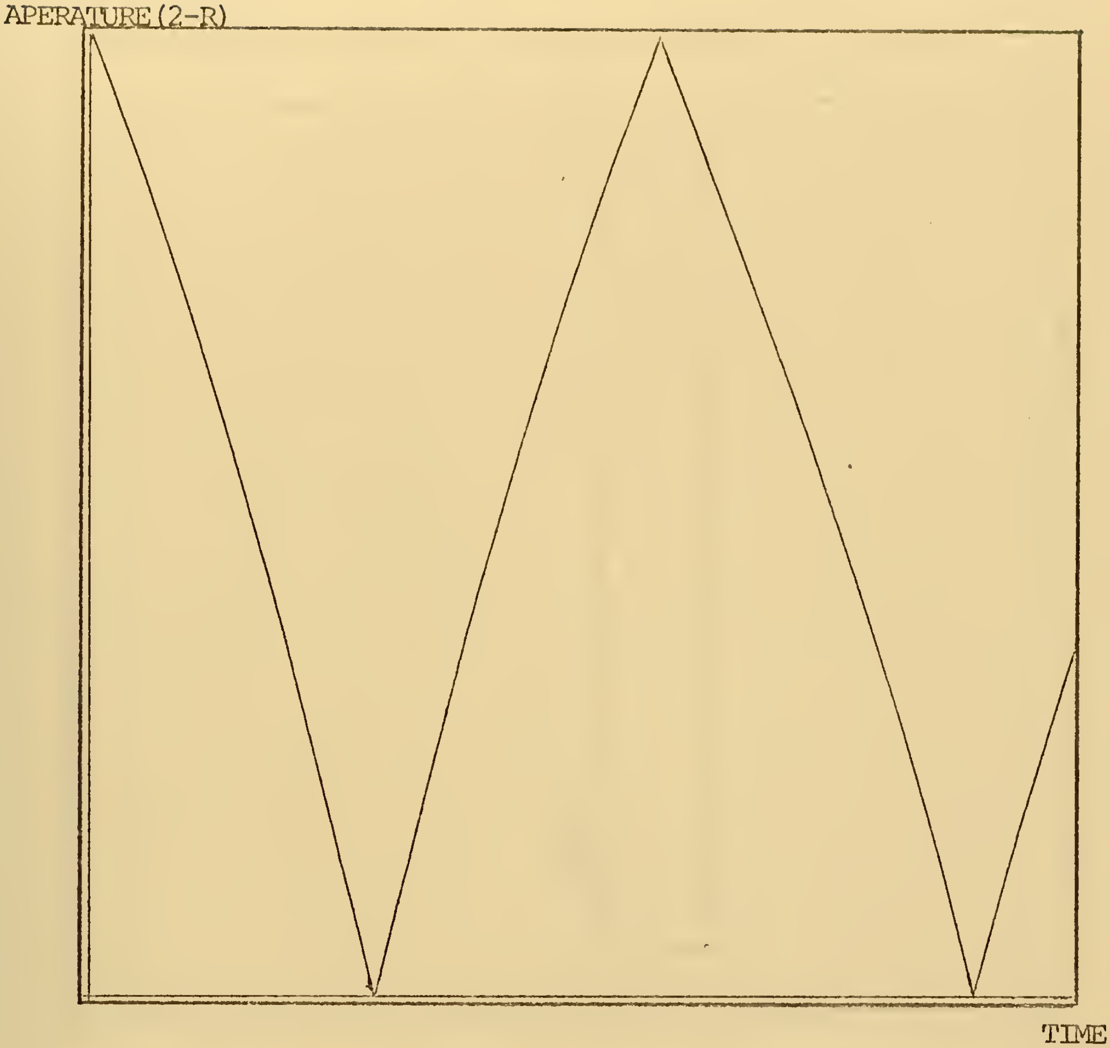
POS1= .0 POS2= 240.0 POSR= .0 TIME= 300

VEL1= .0 VEL2=-165.0 VELR= .0

OPTIONS: 1.CURSOR ON--FNS 3
2.PRINTER PLOT--FNS 12
3.NAMELIST INPUT--FNS 11

FIGURE 12

COMMON AREA GRAPH PAGE



HITE1= 0 HITE2= 24500 HITER 24500 DB= 40.0

R1= .0 R2=190.2 RR=190.2 TRNPTM= .0 TRNPTP= 240.0

POS1= .0 POS2= 240.0 POSR= .0 TIME= 300

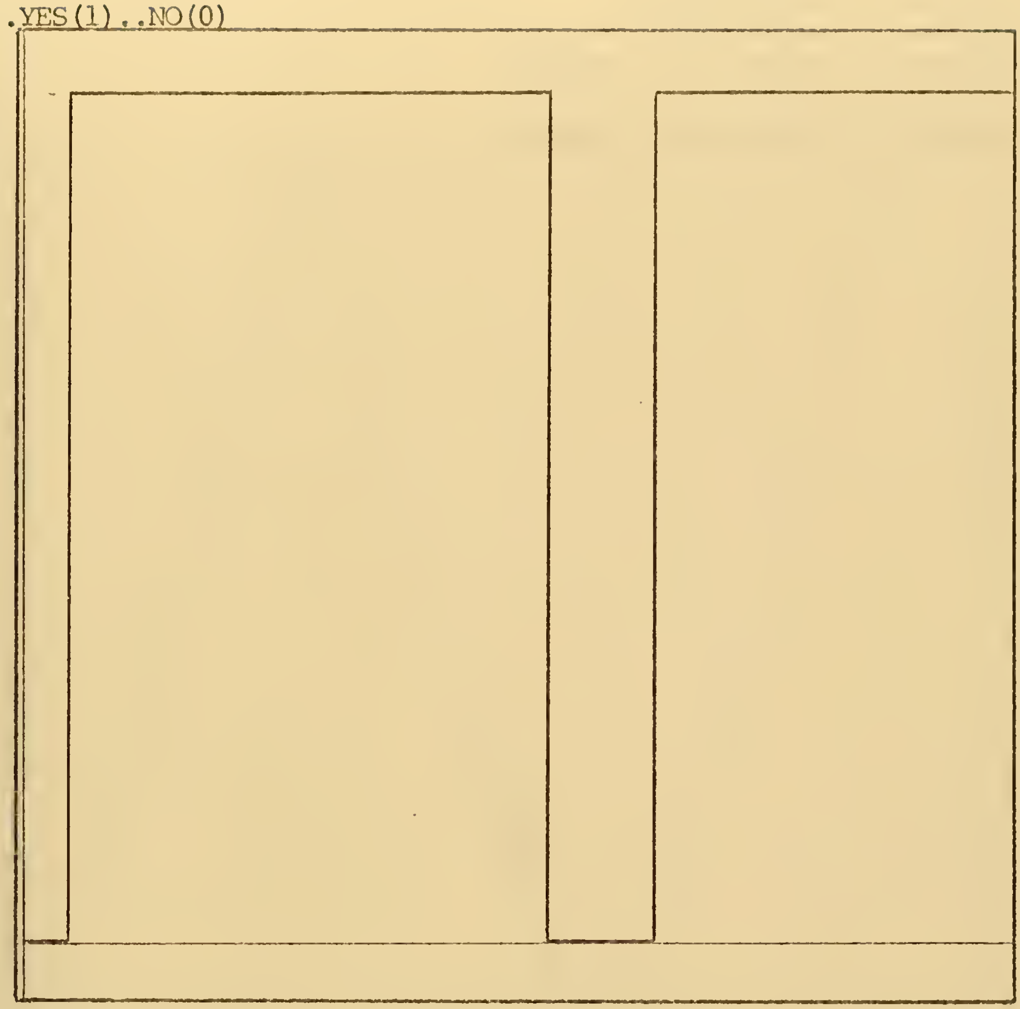
VEL1= .0 VEL2=-165.0 VELR= .0

OPTIONS:	1.CURSOR ON--FNS 3
	2.PRINTER PLOT--FNS 12
	3.NAMELIST INPUT--FNS 11

FIGURE 13

APERATURE GRAPH PAGE

FIX..YES(1)..NO(0)



TIME

HITE1= 0 HITE2=24500 HITER= 24500 DB= 40.0

R1= .0 R2=190.2 RR=190.2 TRNPTM= .0 TRNPTP= 240.0

POS1= .0 POS2= 240.0 POSR= .0 TIME= 300

VEL1= .0 VEL2=-165.0 VELR= .0

OPTIONS: 1.CURSOR ON--FNS 3
2.PRINTER PLOT--FNS 12
3.NAMELIST INPUT--FNS 11

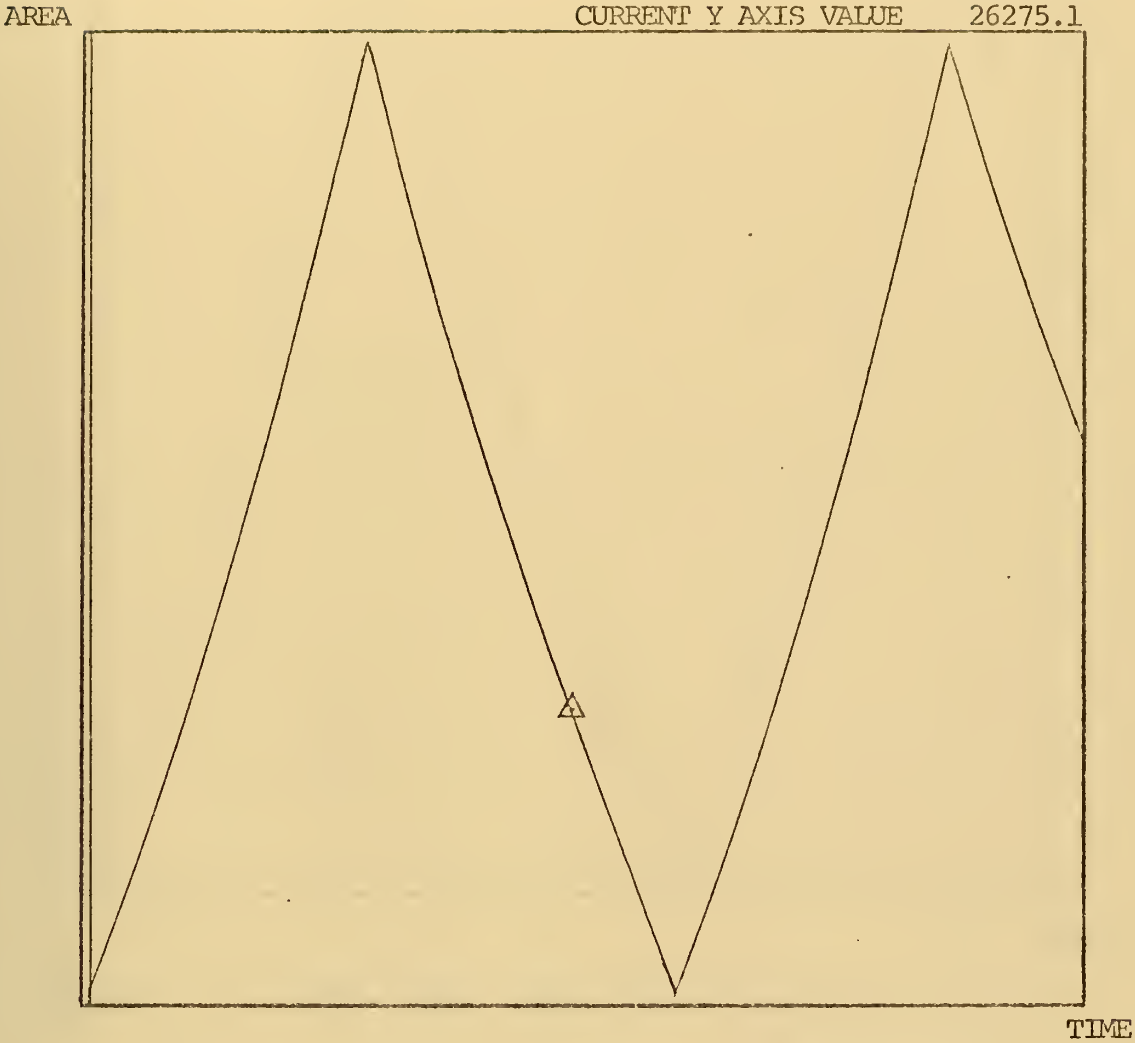
FIGURE 14

POSSIBILITY OF FIX GRAPH PAGE

CURRENT POS2 165.000

CURRENT X AXIS VALUE 148.000

CURRENT Y AXIS VALUE 26275.1



HITE1= 0 HITE2= 24500 HITER= 24500 DB= 40.0

R1= .0 R2=190.2 RR=190.2 TRNPTM= .0 TRNPTP= 240.0

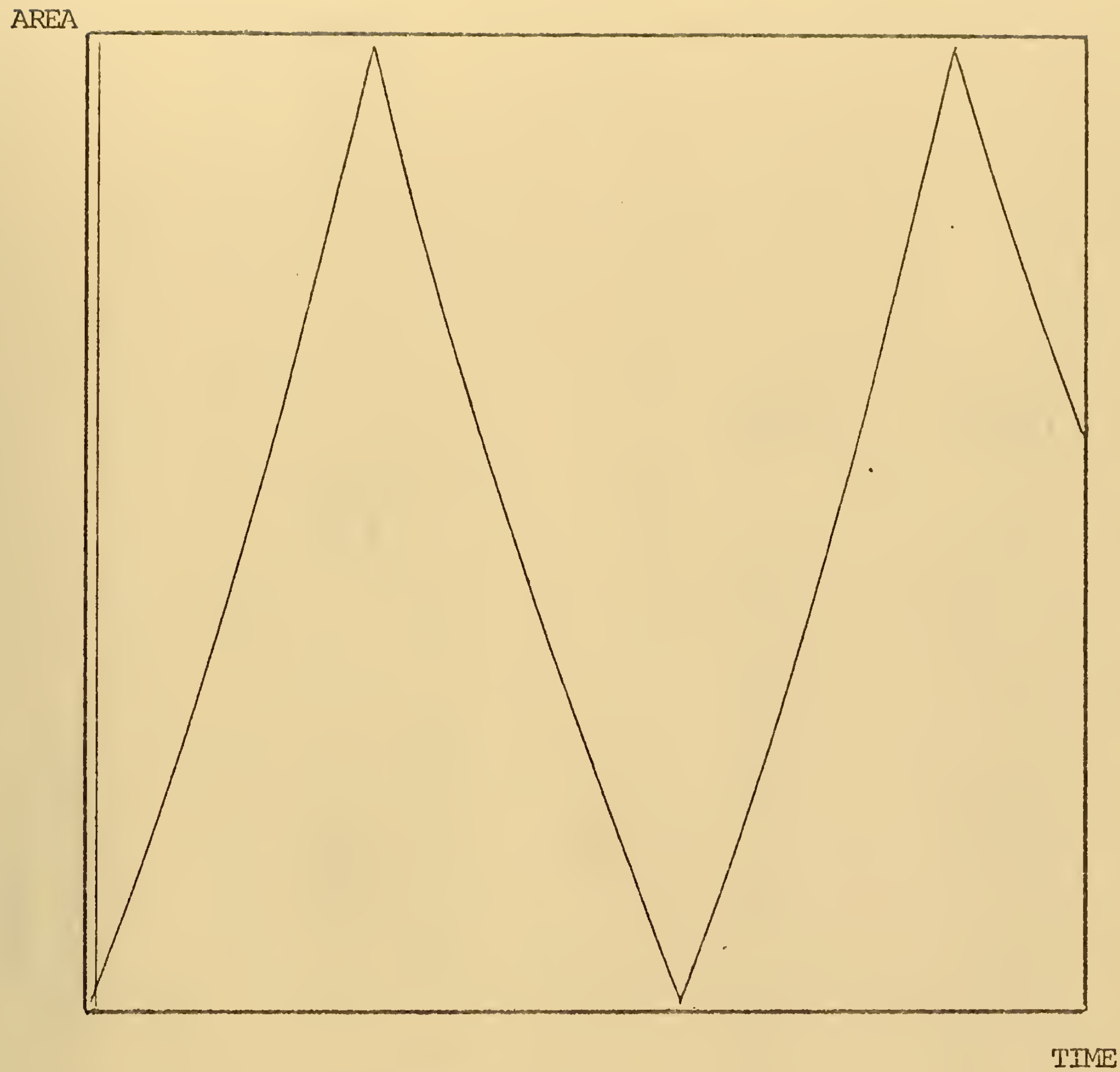
POS1= .0 POS2= 240.0 POSR= .0 TIME= 300

VEL1= .0 VEL2=-165.0 VELR= .0

OPTIONS: 1.MOVE FORWARD--FNS 7
2.MOVE BACK--FNS 8
3.CURSOR OFF--FNS 4

FIGURE 15

COMMON AREA GRAPH WITH 'CURSOR ON' OPTION SELECTED



HITE1= 0 HITE2= 24500 HITER= 24500 DB= 40.0

R1= .0 R2=190.2 RR=190.2 TRNPTM= .0 TRNPTP= 240.0

POS1= .0 POS2= 240.0 POSR= .0 TIME= 300

VEL1= .0 VEL2=-165.0 VELR= .0

OPTIONS: 1.INPUT PARAMETER--TTY
2.EXECUTE--TYPE *C/R
3.END PROGRAM--TYPE IX=1

NAMELIST INPUT

—

FIGURE 16

COMMON AREA GRAPH WITH 'NAMELIST INPUT' OPTION SELECTED

APPENDIX D

COMPUTER OUTPUT

```
THESIS PROGRAM      LT. G. E. ELFERS

          ALTITUDE(FT)/RADIUS(NM)   VELOCITY(MPH)   INITIAL POSITION   TURNING POINTS

AIRCRAFT 1         0    /     .0          .0               .0            .0 / 240.0
AIRCRAFT 2     24000    /  190.2      -170.0            170.0            .0 / 240.0
AIRCRAFT P     24000    /  190.2      -170.0            240.0            .0 / 240.0
DISTANCE TO BORDER IS  36.0 MILES
IF SPECIFIED, TARGET CO-ORDS ARE X=  50.0 , Y= 105.0
TOTAL AIR TIME IS  300 MINUTES


                        STATISTICAL DATA

SEARCH MODE

    PERCENT OF TIME
        1. F.O.V. INTERSECT APERATURE GREATER THAN  20 DEG. ...   76.7
        2. COMMON AREA GREATER THAN 30.0 PCT. OF SEARCH AREA .. 100.0
    PERCENT OF SEARCH AREA COVERED .............................   88.0

TARGET MODE

    PERCENT OF TIME
        1. TARGET IN RANGE OF TWO A/C ..........................   81.3
        2. TWO A/C APERATURE GREATER THAN  20 DEG. ............   62.3
        3. VIEW OF TARGET WITHIN   5.0 MIN. OF TWO A/C ........   86.3
```

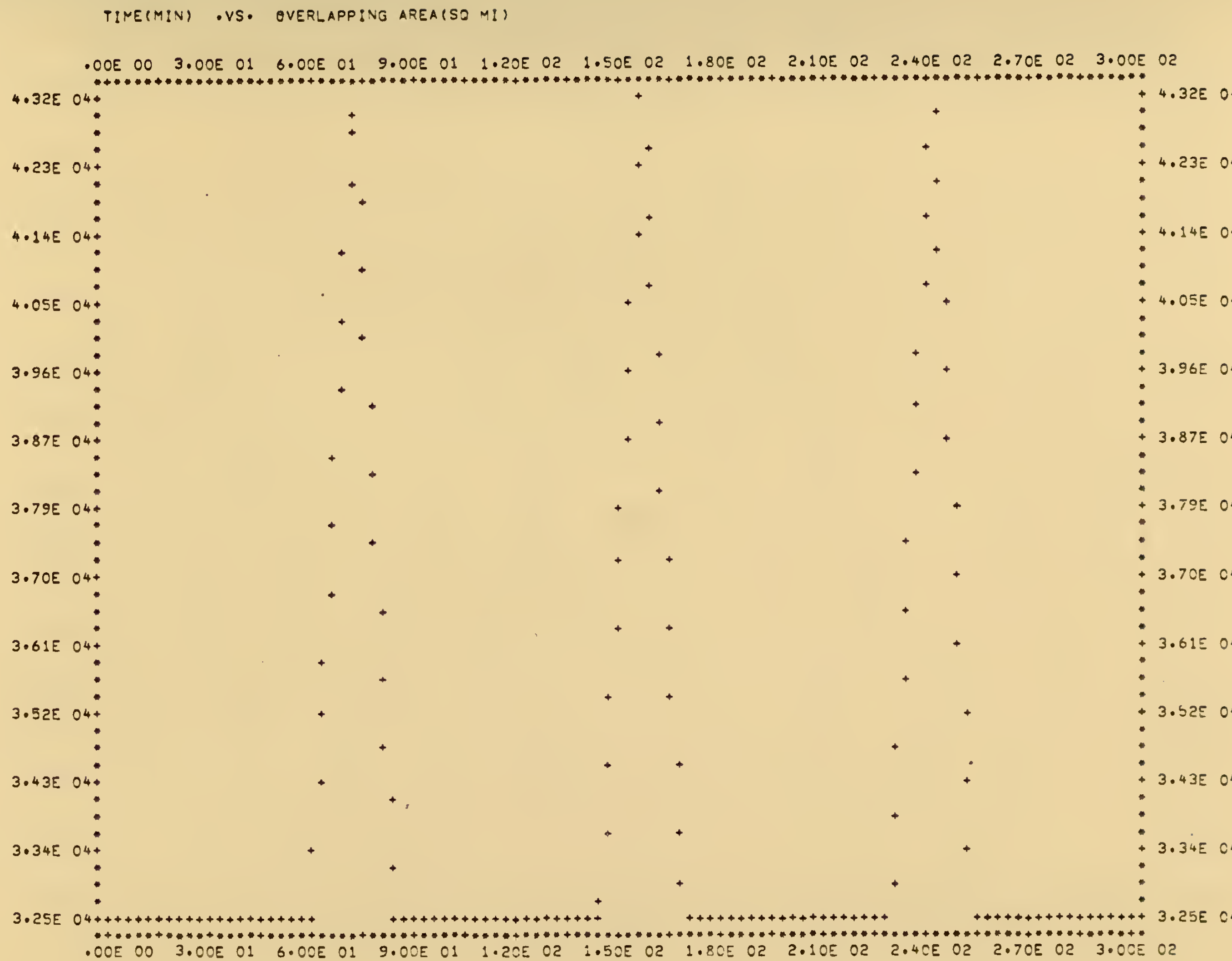
PRINTER OUTPUT - PARAMETER AND STATISTICAL DATA OUTPUT

PRINTER OUTPUT - LEFT HALF OF DATA OUTPUT PAGE

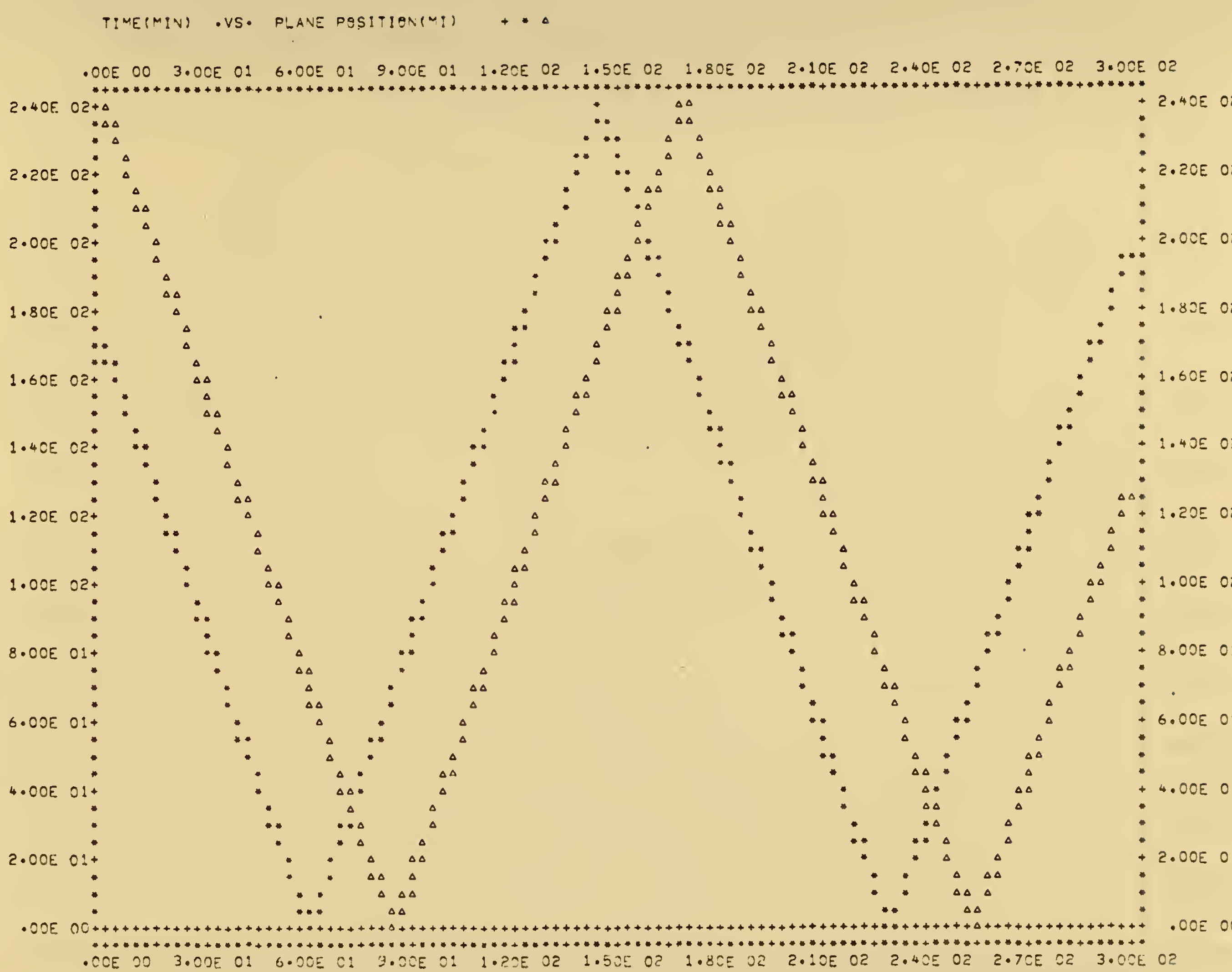
TIME	AREA	POS1	POS2	POSR
.0	32516.18	.0	170.0	240.0
6.0	32516.18	.0	153.0	223.0
12.0	32516.18	.0	136.0	206.0
18.0	32516.18	.0	119.0	189.0
24.0	32516.18	.0	102.0	172.0
30.0	32516.18	.0	85.0	155.0
36.0	32516.18	.0	68.0	138.0
42.0	32516.18	.0	51.0	121.0
48.0	32516.18	.0	34.0	104.0
54.0	32516.18	.0	17.0	87.0
60.0	32517.69	.0	.0	70.0
66.0	37695.32	.0	17.0	53.0
72.0	42929.50	.0	34.0	36.0
78.0	38309.26	.0	51.0	19.0
84.0	33120.91	.0	68.0	2.0
90.0	32516.18	.0	85.0	15.0
96.0	32516.18	.0	102.0	32.0
102.0	32516.18	.0	119.0	49.0
108.0	32516.18	.0	136.0	66.0
114.0	32516.18	.0	153.0	83.0
120.0	32516.18	.0	170.0	100.0
126.0	32516.18	.0	187.0	117.0
132.0	32516.18	.0	204.0	134.0
138.0	32516.18	.0	221.0	151.0
144.0	32516.18	.0	238.0	168.0
150.0	37032.14	.0	225.0	185.0
156.0	42312.56	.0	208.0	202.0
162.0	38923.88	.0	191.0	219.0
168.0	33727.06	.0	174.0	236.0
174.0	32516.18	.0	157.0	227.0
180.0	32516.18	.0	140.0	210.0
186.0	32516.18	.0	123.0	193.0
192.0	32516.18	.0	106.0	176.0
198.0	32516.18	.0	89.0	159.0
204.0	32516.18	.0	72.0	142.0
210.0	32516.18	.0	55.0	125.0
216.0	32516.18	.0	38.0	108.0
222.0	32516.18	.0	21.0	91.0
228.0	32516.18	.0	4.0	74.0
234.0	36469.80	.0	13.0	57.0
240.0	41625.74	.0	30.0	40.0
246.0	39529.09	.0	47.0	23.0
252.0	34334.52	.0	64.0	6.0
258.0	32516.18	.0	81.0	11.0
264.0	32516.18	.0	98.0	28.0
270.0	32516.18	.0	115.0	45.0
276.0	32516.18	.0	132.0	62.0
282.0	32516.18	.0	149.0	79.0
288.0	32516.18	.0	166.0	96.0
294.0	32516.18	.0	183.0	113.0

PRINTER OUTPUT - RIGHT HALF OF DATA OUTPUT PAGE

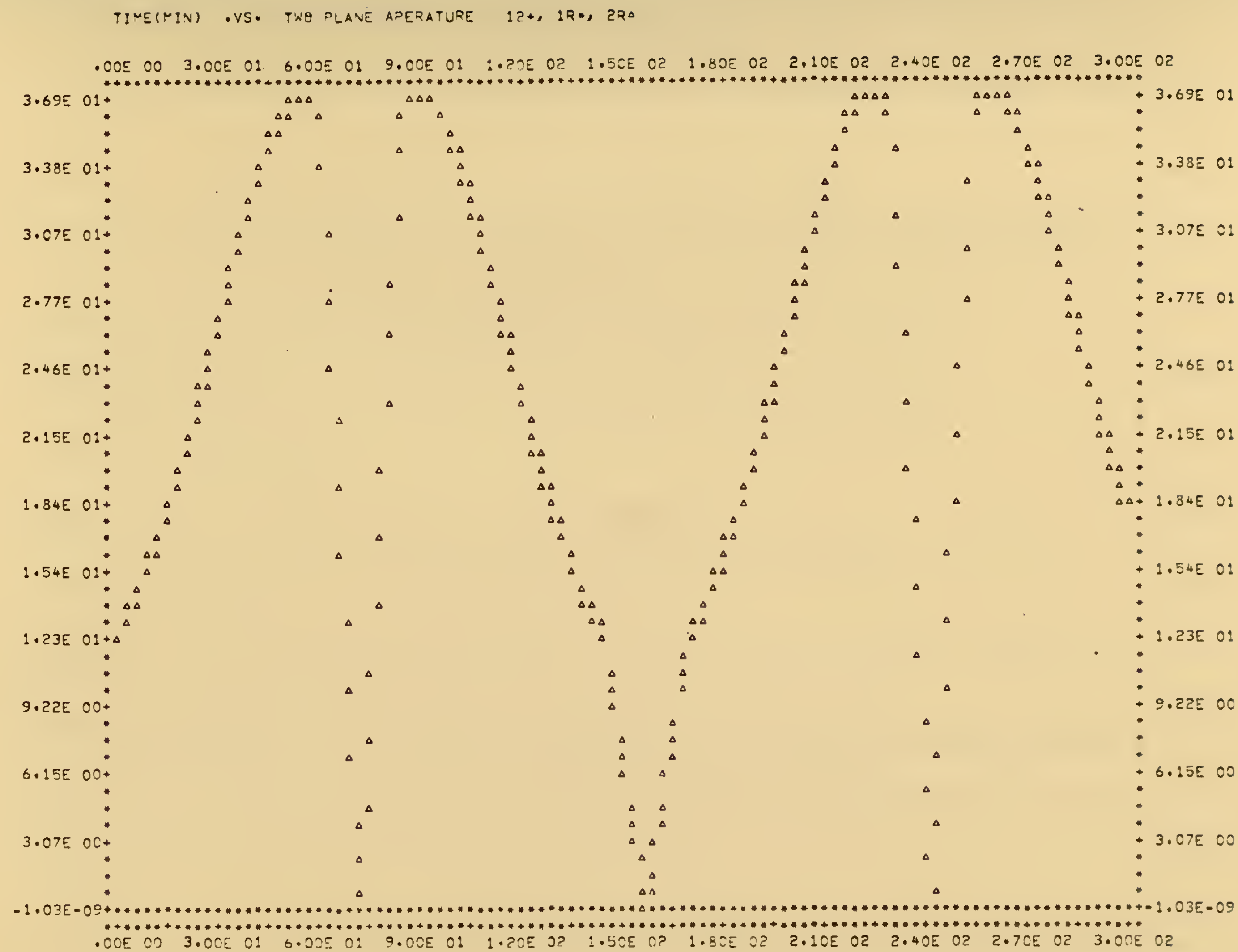
AP12	AP1R	AP2R	1-T	2-T	R-T
.0	.0	12.3	.0	159.5	217.1
.0	.0	14.3	.0	147.1	202.4
.0	.0	16.7	.0	135.7	188.0
.0	.0	19.6	.0	125.6	174.2
.0	.0	22.9	.0	117.2	161.0
.0	.0	26.6	.0	110.7	148.5
.0	.0	30.2	.0	106.5	137.0
.0	.0	33.5	.0	105.0	126.8
.0	.0	35.9	.0	106.2	118.1
.0	.0	36.9	.0	110.1	111.3
.0	.0	36.2	.0	116.3	106.9
.0	.0	19.1	.0	110.1	105.0
.0	.0	1.1	.0	106.2	105.9
.0	.0	17.0	.0	105.0	109.5
.0	.0	34.3	.0	106.5	115.5
.0	.0	36.9	.0	110.7	110.7
.0	.0	36.1	.0	117.2	106.5
.0	.0	33.9	.0	125.6	105.0
.0	.0	30.7	.0	135.7	106.2
.0	.0	27.0	.0	147.1	110.1
.0	.0	23.4	.0	159.5	116.3
.0	.0	20.0	.0	172.6	124.6
.0	.0	17.1	.0	186.4	134.5
.0	.0	14.6	.0	200.7	145.7
.0	.0	12.5	.0	215.3	158.0
.0	.0	6.9	.0	204.1	171.0
.0	.0	1.0	.0	189.7	184.7
.0	.0	4.8	.0	175.8	199.0
.0	.0	10.8	.0	162.5	213.6
.0	.0	13.8	.0	149.9	205.8
.0	.0	16.1	.0	138.3	191.4
.0	.0	18.9	.0	127.9	177.4
.0	.0	22.1	.0	119.0	164.0
.0	.0	25.7	.0	112.0	151.3
.0	.0	29.4	.0	107.3	139.6
.0	.0	32.8	.0	105.1	129.0
.0	.0	35.4	.0	105.7	120.0
.0	.0	36.8	.0	108.9	112.7
.0	.0	36.5	.0	114.6	107.7
.0	.0	23.2	.0	111.3	105.2
.0	.0	5.3	.0	106.9	105.5
.0	.0	12.8	.0	105.0	108.4
.0	.0	30.3	.0	105.9	113.8
.0	.0	36.8	.0	109.5	112.0
.0	.0	36.4	.0	115.5	107.3
.0	.0	34.5	.0	123.5	105.1
.0	.0	31.5	.0	133.2	105.7
.0	.0	27.9	.0	144.3	108.9
.0	.0	24.2	.0	156.5	114.6
.0	.0	20.7	.0	169.5	122.4



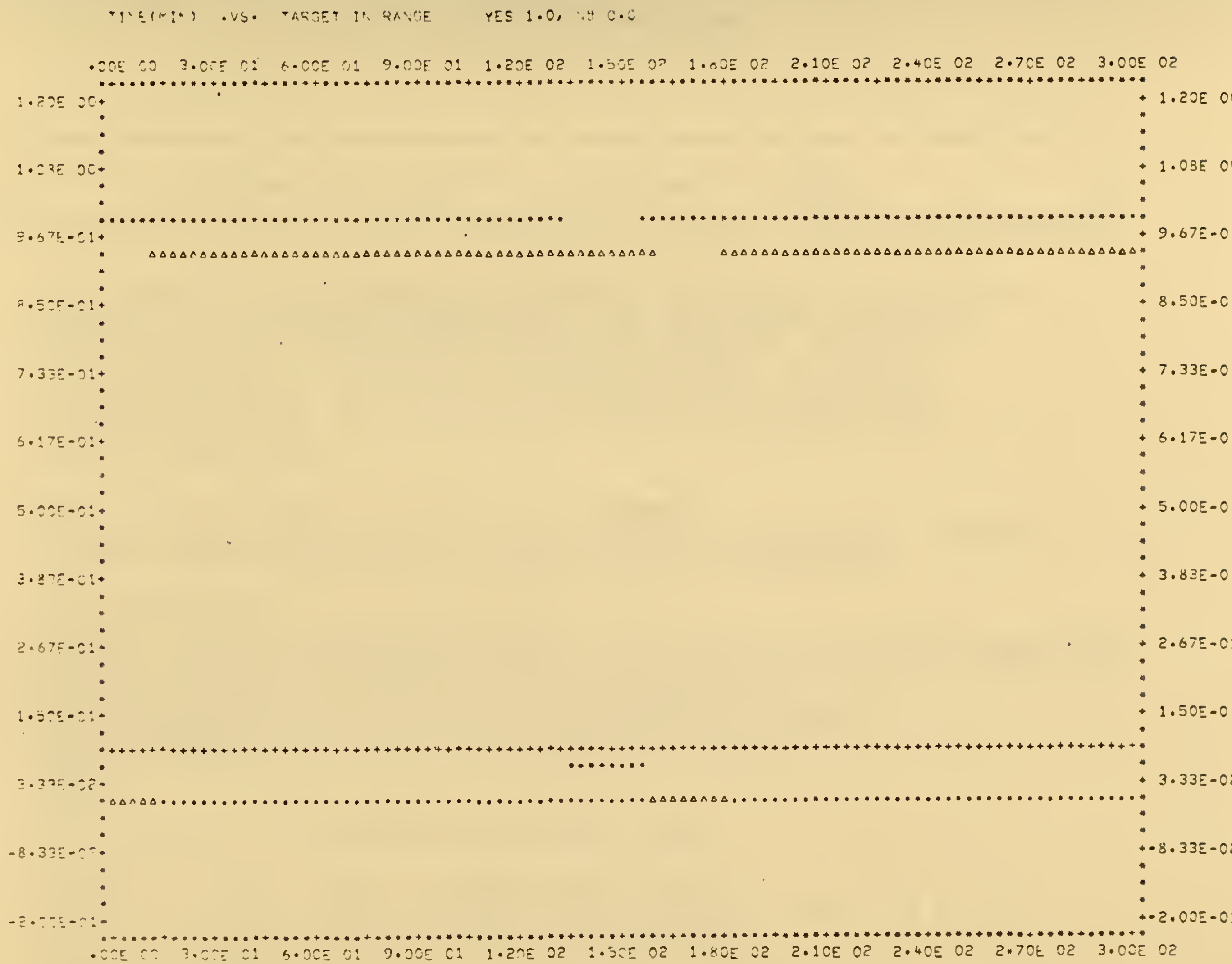
PRINTER PLOT - TIME VERSUS OVERLAPPING AREA



PRINTER PLOT - TIME VERSUS PLANE POSITION



PRINTER PLOT - TIME VERSUS TWO PLANE APERATURE



PRINTER PLOT - TIME VERSUS TARGET IN RANGE

APPENDIX E

COMPUTER PROGRAM

```
C     ***********************************************************************
C     *                                                                     *
C     *               INTERACTIVE GRAPHICS AIRBORNE OF MODEL                *
C     *                                                                     *
C     ***********************************************************************
C
C
C       THIS INTERACTIVE GRAPHICS PROGRAM IS DESIGNED TO SIMULATE
C       AIRBORNE OF MISSIONS USING ONE, TWO, OR THREE AIRCRAFT.
C       DATA SUCH AS AIRCRAFT POSITIONS, OVERLAPPING AREA OF
C       COMMON COVERAGE, APERATURES, AND DISTANCES TO TARGET
C       ARE COMPUTED INCREMENTALLY IN TIME AND ARE AVAILABLE
C       AS PRINTER OUTPUT AND PARTLY AVAILABLE AS A GRAPHICS
C       TERMINAL DISPLAY. SIX STATISTICS ON EACH MISSION RUN
C       ARE ALSO COMPUTED.
C
C
C       TIME/INCR MUST NOT BE GREATER THAN 300
C       AIRCRAFT WITH VISIBILITY OF LESS THAN .5 MILES ARE IGNORED
C       TURNING POINTS MUST BE SPECIFIED FOR ALL A/C USED
C
        REAL INCR,INM
        INTEGER HITE1,HITE2,HITER,TIME
        COMMON POS1,POS2,POSR,HITE1,HITE2,HITER,R1,R2,RR,VEL1,VEL2,VELR,
       1TRNPTM,TRNPTP,TIME,INCR,IX,DB,XP1,XP2,XP3,YP1,YP2,YP3,NERR,IALL
       2,IANGX,IANG,INM,PSA,TP1,TP2,TPR,TM1,TM2,TMR
        DIMENSION DAPT(300),XY(300,5),AP(300,4),DST(300,3)
        EQUIVALENCE(DAPT(1),XY(1,2)),(AP(1,4),XY(1,1))
        NAMELIST IDEV
        IALL=0
        IX=0
        DB=0.0
C       NERR EQUALS 1 OR GREATER FOR ERROR INPUT
        NERR=0
C       IDENTIFY TARGET WITH CO-ORDS XP1...,YP1...
C       CHANGING XP1,XP2 ETC. CHANGES THE APPARENT POSITION OF THE
C       TARGET AS SEEN BY EACH PLANE--ERROR INPUT
        XP1=XP2=XP3=0.0
        YP1=YP2=YP3=0.0
        OUTPUT(101)'TYPE IDEV=1*C/R FOR AGT-1 OR IDEV=2*C/R FOR AGT-2'
```

```
      INPUT(101)
C
C     INPUT FOR PARAMETER INITIALIZATION
C
      READ(5,200)POS1,POS2,POSR
  200 FORMAT(3F10.2)
      READ(5,201)HITE1,HITE2,HITER
  201 FORMAT(3(I6,4X))
      READ(5,202)R1,R2,RR
  202 FORMAT(3F10.2)
      READ(5,203)VEL1,VEL2,VELR
  203 FORMAT(3F10.2)
      READ(5,204)TM1,TP1,TM2,TP2,TMR,TPR
  204 FORMAT(6F10.2)
      READ(5,205)INCR,TIME
  205 FORMAT(F10.2,I4)
      READ(5,206)DB,PSA,INM,IANGX,IANG
  206 FORMAT(3F10.2,2(I3,7X))
      READ(5,207)XP1,XP2,XP3,YP1,YP2,YP3
  207 FORMAT(6F10.2)
    1 CONTINUE
      IF(IX.NE.0)GO TO 37
      CALL DGEN(XY,M,AP,DST,DAPT,IDEV)
      CALL GPLOT(XY,M,IDEV,AP,DST)
      GO TO 1
   37 STOP
      END


      SUBROUTINE DGEN(XY,M,AP,DST,DAPT,IDEV)
C     DATA GENERATION SUBROUTINE
C
      INTEGER HITE1,HITE2,HITER,TIME
      REAL INCR,M1,M2,M3,INM
      COMMON POS1,POS2,POSR,HITE1,HITE2,HITER,R1,R2,RR,VEL1,VEL2,VELR,
     1TRNPTM,TRNPTP,TIME,INCR,IX,DB,XP1,XP2,XP3,YP1,YP2,YP3,NERR,IALL
     2,IANGX,IANG,INM,PSA,TP1,TP2,TPR,TM1,TM2,TMP
      DIMENSION DAPT(300),XY(300,5),AP(300,4),DST(300,7)
      DIMENSION ITDIR(14),ITEXT(17),A(100)
      NTT=INM/INCR+1
      Y1=Y2=Y3=0.0
      IA=0
      IAX=0
      ICA=0
      IPT=0
      IDST=0
      IF(NERR.NE.0)GO TO 700
      XP2=XP1
```

```
      XF3=XP1
      YF2=YP1
      YF3=YP1
  700 CONTINUE
C     INITIALIZES DAPT TO 0
C     INITIALIZES XY MATRIX TO 0.0 FOR PLOT ROUTINE
      DO 3 K=1,5
      DO 3 J=1,300
      XY(J,K)=0.0
    3 CONTINUE
C
C     CONVERT HITEX TO RADIUS, RX, IN NAUTICAL MILES
C
      IF(HITE1.GT.0)R1=SQRT(2.0*HITE1)/1.1516
      IF(HITE2.GT.0)R2=SQRT(2.0*HITE2)/1.1516
      IF(HITER.GT.0)RR=SQRT(2.0*HITER)/1.1516
C     PARAMETER SETUP FOR STATISTICAL DATA SECTION
      TRNPTM=AMIN(TM1,TM2,TMR)
      TRNPTP=AMAX(TP1,TP2,TPR)
      AMACS=AMIN(RR,R2)
      SAREA=(TRNPTP-TRNPTM)*(AMACS-DB)+2.0*XAREA1(AMACS,AMACS-DB)
      XN=TRNPTM-SQRT(AMACS**2-DB**2)
      XK=(TRNPTP-TRNPTM+2.0*SQRT(AMACS**2-DB**2))/99.0
      DO 333 NN=1,100
      A(NN)=XN+(NN-1)*XK
  333 CONTINUE
      M=TIME/INCR
      BC=DB
C
C     BORDER CORRECTION
C
      FRAC1=0.0
      IF(R1-DB.LE.0.0)GO TO 4
      FRAC1=XAREA1(R1,R1-DB)*2.0/AREA(R1)
    4 FRAC2=0.0
      IF(R2-DB.LE.0.0)GO TO 5
      FRAC2=XAREA1(R2,R2-DB)*2.0/AREA(R2)
    5 FRACR=0.0
      IF(RR-DB.LE.0.0)GO TO 6
      FRACR=XAREA1(RR,RR-DB)*2.0/AREA(RR)
    6 CONTINUE
    2 DO 90 I=1,M
      ISET1=0
      ISET2=0
      ISET3=0
      ISET4=0
      ISET5=0
      ISET6=0
```

```
      JSET12=0
      JSET13=C
      JSET23=0
      KSET1=0
      KSET2=C
      KSET3=0
      KEY=0
      IK=C
      Y23=0
      NPT=0
      C1=ABS(PCS1-POS2)
      C2=ABS(PCS1-POSR)
      C3=ABS(PCS2-POSR)
      IF(C1.GT..01.AND.C2.GT..01.AND.C3.GT..01)GC TC 100
      PT1=POS1
      PT2=PCS2
      PT3=POSR
      PCS1=INT(PCS1*100.0)*.01
      PCS2=INT(PCS2*100.C)*.01
      PCSR=INT(PCSR*100.C)*.01
      NPT=1
C
C     TEST FOR ANY TWO TCTALLY INCLUSIVE FIELDS CF VIEW
C
  1CC CCNTINUE
      IF((POS1+R1.LE.PCS2+R2.AND.PCS1-R1.LE.PCS2+R2)
     1.AND.(PCS1+R1.GE.PCS2-R2.AND.PCS1-R1.GE.PCS2-R2))GO TO 11
  1C1 IF((POS2+R2.LE.PCS1+R1.AND.PCS2-R2.LE.PCS1+R1)
     1.AND.(PCS2+R2.GE.PCS1-R1.AND.POS2-R2.GE.PCS1-R1))GO TO 12
  1C2 IF((PCS1+R1.LE.PCSR+RR.AND.PCS1-R1.LE.PCSR+RR)
     1.AND.(PCS1+R1.GE.PCSR-RR.AND.POS1-R1.GE.PCSR-RR))GC TO 13
  1C3 IF((POSR+RR.LE.PCS1+R1.AND.POSR-RR.LE.PCS1+R1)
     1.AND.(PCSR+RR.GE.PCS1-R1.AND.POSR-RR.GE.PCS1-R1))GO TO 14
  1C4 IF((POS2+R2.LE.PCSR+RR.AND.PCS2-R2.LE.PCSR+RR)
     1.AND.(PCS2+R2.GE.PCSR-RR.ANC.POS2-R2.GE.PCSR-RR))GC TO 15
  1C5 IF((POSR+RR.LE.PCS2+R2.AND.POSR-RR.LE.PCS2+R2)
     1.AND.(PCSR+RR.GE.PCS2-R2.AND.POSR-RR.GE.PCS2-R2))GO TO 16
  1C6 CCNTINUE
      IF(ISET1.LE.0.AND.ISET2.LE.0.AND.ISET3.LE.C.AND.ISET4.LE.0
     1.ANC.ISET5.LE.0.ANC.ISET6.LE.0)GC TO 22
      GC TO 2C
   11 ISET1=1
      DAPT(I)=AREA(R1)*FRAC1
      GC TO 1C2
   12 ISET2=1
      DAPT(I)=AREA(R2)*FRAC2
      GC TC 102
   13 ISET3=1
```

```
      DAPT(I)=DAPT(I)+AREA(R1)*FRAC1
      GO TO 104
   14 ISET4=1
      DAPT(I)=DAPT(I)+AREA(RR)*FRACR
      GO TO 104
   15 ISET5=1
      IK=1
      DAPT(I)=DAPT(I)+AREA(R2)*FRAC2
      GO TO 106
   16 ISET6=1
      IK=2
      DAPT(I)=DAPT(I)+AREA(RR)*FRACR
      GO TO 106
C
C     TEST FOR ALL THREE FIELDS OF VIEW INCLUSIVE
C
   20 CONTINUE
      IF(ISET1.EQ.1.AND.ISET5.EQ.1.OR.ISET3.EQ.1.AND.ISET6.EQ.1
     1.OR.ISET2.EQ.1.AND.ISET3.EQ.1.OR.ISET5.EQ.1.AND.ISET4.EQ.1
     2.OR.ISET4.EQ.1.AND.ISET1.EQ.1.OR.ISET6.EQ.1.AND.ISET2.EQ.1)
     3GO TO 21
      GO TO 22
   21 RMIN=AMIN1(R1,R2,RR)
      IF(RMIN-DB.LE.0.0)GO TO 80
      FRAC=XAREA1(RMIN,RMIN-DB)*2.0/AREA(RMIN)
      DAPT(I)=DAPT(I)-RMIN**2*3.14159*FRAC
      GO TO 80
C
C     TEST FOR PARTIAL FIELD OF VIEW OVERLAP
C
   22 IF(((POS1-R1.LT.POS2+R2).AND.(POS1-R1.GT.POS2-R2).AND.(POS1+R1.GT.
     2POS2+R2)).OR.((POS1-R1.LT.POS2-R2).AND.(POS1+R1.GT.POS2-R2)
     2.AND.(POS1+R1.LT.POS2+R2)))GO TO 31
   41 IF(((POS1-R1.LT.POSR+RR).AND.(POS1-R1.GT.POSR-RR).AND.(POS1+R1
     1.GT.POSR+RR)).OR.((POS1-R1.LT.POSR-RR).AND.(POS1+R1.GT.POSR-RR)
     2.AND.(POS1+R1.LT.POSR+RR)))GO TO 32
   42 IF(((POS2-R2.LT.POSR+RR).AND.(POS2-R2.GT.POSR-RR).AND.(POS2+R2
     1.GT.POSR+RR)).OR.((POS2-R2.LT.POSR-RR).AND.(POS2+R2.GT.POSR-RR)
     2.AND.(POS2+R2.LT.POSR+RR)))GO TO 33
      IF(JSET12.LE.0.AND.JSET13.LE.0.AND.JSET23.LE.0)GO TO 80
      GO TO 89
C
C     CALCULATION OF X AND Y CO-ORD OF OVERLAP
C
   31 JSET12=1
      X12=XINT(POS1,POS2,R1,R2)
      Y12=YINT(X12,R2,POS2)
      GO TO 41
```

```
   32 JSET13=1
      X13=XINT(PCS1,POSR,R1,RR)
      Y13=YINT(X13,RR,PCSR)
      GC TO 42
   33 JSET23=1
      X23=XINT(PCS2,POSR,R2,RR)
      Y23=YINT(X23,RR,PCSR)
C
C     CALCULATICN OF OVERLAPPING AREAS
C
   89 IF(JSET12.EQ.1)GC TC 61
   91 IF(JSET13.EQ.1)GC TC 62
   92 IF(JSET23.EQ.1)GC TC 63
      GC TO 93
   61 CCNTINUE
C     THIS SECTICN FINDS THE NEAREST CIRCLE EDGE TO X AND THEN
C     CHECKS TC SEE WHETHER THAT ECGE IS INSIDE THE LARGER CIRCLE CF INTERSECT
C     TAR IS THE CALC AREA AFTER EDGE CHECK
      TAR12=0.0
      IF(CB.GE.Y12)DB=Y12
      X=X12
      Y=Y12
      IF(R1.GE.R2)GO TC 51
      ECGE=PCS1-R1
      IF(PCS1+R1-X.LT.X-PCS1+R1)ECGE=PCS1+R1
      IF(ECGE.LT.PCS2+R2.ANC.ECGE.GT.PCS2-R2)GC TC 64
      IF(BC.GE.R1)GO TO 65
      TAR12=AREA(R1)*FRAC1+XAREA1(R2,R2-ABS(X-PCS2))+XAREA1(R2,R2-CE)
     1+CE*ABS(X-POS2)-.5*AREA(R2)-XAREA1(R1,R1-AES(X-PCS1))-XAREA1(R1
     2,R1-CB)-DB*ABS(X-PCS1)+.5*AREA(R1)
      GC TO 65
   64 CCNTINUE
      IF(BD.GE.Y12)GO TC 65
      TAR12=XAREA(R1,R1-ABS(X-POS1),R2,R2-ABS(X-PCS2))+XAREA1(R1,R1-CB)
     1+CB*ABS(X-PCS1)-.5*AREA(R1)+XAREA1(R2,R2-CE)+CB*ABS(X-PCS2)
     2-.5*AREA(R2)
   65 CAPT(I)=DAPT(I)+TAR12
      CB=BD
      GC TO 91
   62 CCNTINUE
      TAR13=0.0
      IF(CB.GE.Y13)DB=Y13
      X=X13
      Y=Y13
      IF(R1.GE.RR)GO TO 52
      ECGE=PCS1-R1
      IF(PCS1+R1-X.LT.X-PCS1+R1)EDGE=PCS1+R1
      IF(EDGE.LT.PCSR+RR.ANC.ECGE.GT.PCSR-RR)GC TO 66
```

```
      IF(BC.GE.R1)GO TO 67
      TAR13=AREA(R1)*FRAC1+XAREA1(RR,RR-ABS(X-POSR))+XAREA1(RR,RR-CE)
     1+CB*ABS(X-POSR)-.5*AREA(RR)-XAREA1(R1,R1-ABS(X-POS1))-XAREA1(R1
     2,R1-CB)-CB*ABS(X-POS1)+.5*AREA(R1)
      GO TO 67
   66 CONTINUE
      IF(BD.GE.Y13)GO TO 67
      TAR13=XAREA(R1,R1-ABS(X-POS1),RR,RR-ABS(X-POSR))+XAREA1(R1,R1-CB)
     1+CB*ABS(X-POS1)-.5*AREA(R1)+XAREA1(RR,RR-CE)+CB*ABS(X-POSR)
     2-.5*AREA(RR)
   67 DAPT(I)=CAPT(I)+TAR13
      CB=BD
      GO TO 92
   63 CONTINUE
      TAR23=0.0
      IF(CB.GE.Y23)DB=Y23
      X=X23
      Y=Y23
      IF(R2.GE.RR)GO TO 53
      EDGE=POS2-R2
      IF(POS2+R2-X.LT.X-POS2+R2)EDGE=POS2+R2
      IF(EDGE.LT.POSR+RR.AND.EDGE.GT.POSR-RR)GO TO 68
      IF(BC.GE.R2)GO TO 69
      IK=1
      TAR23=AREA(R2)*FRAC2+XAREA1(RR,RR-ABS(X-POSR))+XAREA1(RR,RR-CE)
     1+CB*ABS(X-POSR)-.5*AREA(RR)-XAREA1(R2,R2-ABS(X-POS2))-XAREA1(R2
     2,R2-CB)-CB*ABS(X-POS2)+.5*AREA(R2)
      GO TO 69
   68 CONTINUE
      IF(BD.GE.Y23)GO TO 69
      TAR23=XAREA(R2,R2-ABS(X-POS2),RR,RR-ABS(X-POSR))+XAREA1(R2,R2-CB)
     1+CB*ABS(X-POS2)-.5*AREA(R2)+XAREA1(RR,RR-CE)+CB*ABS(X-POSR)
     2-.5*AREA(RR)
   69 DAPT(I)=CAPT(I)+TAR23
      CB=BD
      GO TO 93
   51 TEMP1=R1
      TEMP2=R2
      FRACA=FRAC1
      FRACB=FRAC2
      REPL1=POS1
      REPL2=POS2
      KEY=1
      GO TO 54
   52 TEMP1=R1
      TEMP2=RR
      FRACA=FRAC1
      FRACB=FRACR
```

```
      REPL1=PCS1
      REPL2=PCSR
      KEY=2
      GC TO 54
   53 TEMP1=R2
      TEMP2=RR
      FRACA=FRAC2
      FRACB=FRACR
      REPL1=PCS2
      REPL2=PCSR
      KEY=3
   54 EDGE=REPL2-TEMP2
      TAR=0.0
      IF(REPL2+TEMP2-X.LT.X-REPL2+TEMP2)EDGE=REPL2+TEMP2
      IF(EDGE.LT.REPL1+TEMP1.AND.EDGE.GT.REPL1-TEMP1)GC TC 55
      IF(BD.GE.TEMP2)GC TO 56
      IK=2
      TAR=AREA(TEMP2)*FRACB+XAREA1(TEMP1,TEMP1-ABS(X-REPL1))
     1+XAREA1(TEMP1,TEMP1-DB)+DB*ABS(X-REPL1)-.5*AREA(TEMP1)
     2-XAREA1(TEMP2,TEMP2-ABS(X-REPL2))-XAREA1(TEMP2,TEMP2-DB)
     3-DB*ABS(X-REPL2)+.5*AREA(TEMP2)
      GC TO 56
   55 CCNTINUE
      IF(BD.GE.Y)GC TO 56
      TAR=XAREA(TEMP2,TEMP2-ABS(X-REPL2),TEMP1,TEMP1-ABS(X-REPL1))
     1+XAREA1(TEMP2,TEMP2-DB)+DB*ABS(X-REPL2)-.5*AREA(TEMP2)
     2+XAREA1(TEMP1,TEMP1-DB)+DB*ABS(X-REPL1)-.5*AREA(TEMP1)
   56 DAPT(I)=DAPT(I)+TAR
      IF(KEY.EQ.1)TAR12=TAR
      IF(KEY.EQ.2)TAR13=TAR
      IF(KEY.EQ.3)TAR23=TAR
      DB=BD
      GC TC (91,92,93),KEY
   93 CCNTINUE
C
C     CCRRECTICN FOR REDUNDANT CALC OF AREAS
C
      IF(X12.LE.POSR+RR.AND.X12.GE.POSR-RR.AND.JSET12.EQ.1)GO TO 120
  121 IF(X13.LE.PCS2+R2.AND.X13.GE.POS2-R2.AND.JSET13.EQ.1)GO TO 122
  123 IF(X23.LE.PCS1+R1.AND.X23.GE.POS1-R1.AND.JSET23.EQ.1)GC TO 124
      GC TO 125
  120 Y123=YINT(X12,RR,PCSR)
      IF(Y12.GT.Y123)GO TC 121
      KSET1=1
      DAPT(I)=DAPT(I)-TAR12*2.0
      GC TO 121
  122 Y132=YINT(X13,R2,PCS2)
      IF(Y13.GT.Y132)GC TC 123
```

```
      KSET2=1
      DAPT(I)=DAPT(I)-TAR13*2.0
      GO TO 123
  124 Y231=YINT(X23,R1,POS1)
      IF(Y23.GT.Y231)GO TO 125
      KSET3=1
      DAPT(I)=DAPT(I)-TAR23*2.0
  125 IF(KSET1.EQ.1.AND.KSET3.EQ.1)DAPT(I)=DAPT(I)+AREA(R2)*2.0
     1*FRAC2
      IF(KSET1.EQ.1.AND.KSET2.EQ.1)DAPT(I)=DAPT(I)+AREA(R1)*2.0
     1*FRAC1
      IF(KSET2.EQ.1.AND.KSET3.EQ.1)DAPT(I)=DAPT(I)+AREA(RR)*2.0
     1*FRACR
   80 CONTINUE
C
C     APERATURE AND DISTANCE TO TARGET CALCULATIONS
C     AP(I,1) IS BETWEEN PLANES ONE AND TWO
C     AP(I,2) IS BETWEEN PLANES ONE AND THREE
C     AP(I,3) IS BETWEEN PLANES TWO AND THREE
C
      IF(XP1.EQ.0.0.AND.YP1.EQ.0.0)GO TO 7
      M1=(YP1-Y1)/(XP1-POS1)
      IF(ABS(XP1-POS1).LE..02)M1=10000.0
      M2=(YP2-Y2)/(XP2-POS2)
      IF(ABS(XP2-POS2).LE..02)M2=10000.0
      M3=(YP3-Y3)/(XP3-POSR)
      IF(ABS(XP3-POSR).LE..02)M3=10000.0
      SN=1.0
      IF(POS1.LE.POS2)SN=-1.0
      AARG=SN*((M2-M1)/(1.0+M1*M2))
      AP(I,1)=ATAN(AARG)*360.0/6.283
      DST(I,1)=SQRT((POS1-XP1)**2+(YP1-Y1)**2)
      IF(AP(I,1).GT.0.0)AP(I,1)=180.0-AP(I,1)
      IF(AP(I,1).LT.0.0)AP(I,1)=-AP(I,1)
      IF(R1.LT.0.5)DST(I,1)=0.0
      IF(R1.LT.0.5.OR.R2.LT.0.5)AP(I,1)=0.0
      SN=1.0
      IF(POS1.LE.POSR)SN=-1.0
      AARG=SN*((M3-M1)/(1.0+M1*M3))
      AP(I,2)=ATAN(AARG)*360.0/6.283
      DST(I,2)=SQRT((POS2-XP2)**2+(YP2-Y2)**2)
      IF(AP(I,2).GT.0.0)AP(I,2)=180.0-AP(I,2)
      IF(AP(I,2).LT.0.0)AP(I,2)=-AP(I,2)
      IF(R2.LT.0.5)DST(I,2)=0.0
      IF(R1.LT.0.5.OR.RR.LT.0.5)AP(I,2)=0.0
      SN=1.0
      IF(POSR.LE.POS2)SN=-1.0
      AARG=SN*((M2-M3)/(1.0+M2*M3))
```

```
      AP(I,3)=ATAN(AARG)*360.0/6.283
      DST(I,3)=SQRT((POSR-XP3)**2+(YP3-Y3)**2)
      IF(RR.LT.0.5)DST(I,3)=0.0
      IF(R2.LT.0.5.OR.RR.LT.0.5)AP(I,3)=0.0
      IF(AP(I,3).GT.0.0)AP(I,3)=180.0-AP(I,3)
      IF(AP(I,3).LT.0.0)AP(I,3)=-AP(I,3)
    7 CONTINUE
      XY(I,1)=INCR*I-INCR
      XY(I,3)=PCS1
      XY(I,4)=PCS2
      XY(I,5)=PCSR
      IF(I.GT.1)GO TO 126
      SVEL1=VEL1
      SVEL2=VEL2
      SVELR=VELR
  126 CONTINUE
C
C     STATISTICAL DATA CALCULATIONS
C
      IF(IK.NE.1)GO TO 127
      X23=POS2
      Y23=R2
  127 IF(IK.NE.2)GO TO 128
      X23=POSR
      Y23=RR
  128 CONTINUE
      IAPX=APX(X23,Y23,PCS2,PCSR)
      IF(IANGX.LE.IAPX)IAX=1+IAX
      PCNT2=(DAPT(I)/SAREA)*100.0
      IF(PCNT2.GT.PSA)ICA=1+ICA
      IF(R2.GE.DST(I,2).AND.RR.GE.DST(I,3))IPT=1+IPT
      IAP=AP(I,3)
      IF(IANG.LE.IAP.AND.R2.GE.DST(I,2).AND.RR.GE.DST(I,3))IA=IA+1
C     CALCULATION FOR PERCENTAGE OF SEARCH AREA COVERED
      DO 330 N=1,100
      IF(A(N).GE.10000.0)GO TO 330
      DS2=SQRT((POS2-A(N))**2+DB**2)
      DS3=SQRT((PCSR-A(N))**2+DB**2)
      IF(R2.GE.DS2.AND.RR.GE.DS3)GO TO 332
      GO TO 330
  332 IDST=IDST+1
      A(N)=10001.0
  330 CONTINUE
C     PARAMETER ADJUSTMENT FOR NEXT RUN THRU LOOP
      IF(NPT.NE.1)GO TO 17
      PCS1=PT1
      PCS2=PT2
      PCSR=PT3
```

```
17 CCNTINUE
   PCS1=PCS1+VEL1*INCR/60.0
   PCS2=POS2+VEL2*INCR/6C.0
   PCSR=POSR+VELR*INCR/60.0
   IF(POS1.GT.TP1)GC TC 71
   IF(PCS1.LT.TM1)GC TC 72
82 IF(POS2.GT.TP2)GO TO 73
   IF(POS2.LT.TM2)GC TC 74
84 IF(POSR.GT.TPR)GO TC 75
   IF(PCSR.LT.TMR)GO TC 76
   GC TO 9C
71 PCS1=2.0*TP1-POS1
   VEL1=-VEL1
   GC TO 82
72 PCS1=2.0*TM1-PCS1
   VEL1=-VEL1
   GC TO 82
73 PCS2=2.0*TP2-POS2
   VEL2=-VEL2
   GC TO 84
74 PCS2=2.C*TM2-PCS2
   VEL2=-VEL2
   GC TO 84
75 PCSR=2.C*TPR-POSR
   VELR=-VELR
   GC TO 9C
76 PCSR=2.C*TMR-PCSR
   VELR=-VELR
9C CCNTINUE
C     CALCULATICN FCR PERCENTAGE CF TIME VIEW CF TARGET
C     WITHIN INM MINUTES CF TWO A/C
   IJK=0
   DC 8 L=1,M
   IAA=0
   IBB=0
   DC 9 K=1,NTT
   K1=L+K-1
   IF((IAA.EQ.1.AND.IBB.EQ.1).OR.K1.GT.M)GO TC 8
   IF(R2.GE.DST(K1,2))IAA=1
   IF(RR.GE.DST(K1,3))IBB=1
   IF(IAA.NE.1.OR.IBB.NE.1)GO TO 9
   IJK=IJK+1
 9 CCNTINUE
 8 CCNTINUE
   STAT1=(IAX/M)*100.C
   STAT2=(ICA/M)*100.C
   STAT3=(IPT/M)*100.C
   STAT4=(IA/M)*100.C
```

```
      STAT5=(IJK/M)*100.0
      STAT6=ICST
C     RE-INITIALIZES PCS1,PCS2,POSR
      PCS1=XY(1,3)
      PCS2=XY(1,4)
      PCSR=XY(1,5)
      VEL1=SVEL1
      VEL2=SVEL2
      VELR=SVELR
C
C     PARAMETER AND STATISTICAL DATA PRINTOUT SECTION
C
      WRITE(6,701)
  701 FORMAT(14X,'ALTITUDE(FT)/RADIUS(NM)   VELOCITY(MPH)   INITIAL POSI
     1TION   TURNING POINTS',/)
      WRITE(6,702)HITE1,R1,VEL1,XY(1,3),TM1,TP1
  702 FORMAT(2X,'AIRCRAFT 1  ',2X,I6,4X,'/',2X,F5.1,8X,F6.1,11X,F7.1,
     19X,F6.1,' /',F6.1)
      WRITE(6,703)HITE2,R2,VEL2,XY(1,4),TM2,TP2
  703 FORMAT(2X,'AIRCRAFT 2  ',2X,I6,4X,'/',2X,F5.1,8X,F6.1,11X,F7.1,
     19X,F6.1,' /',F6.1)
      WRITE(6,704)HITER,RR,VELR,XY(1,5),TMR,TPR
  704 FORMAT(2X,'AIRCRAFT R  ',2X,I6,4X,'/',2X,F5.1,8X,F6.1,11X,F7.1,
     19X,F6.1,' /',F6.1)
      WRITE(6,707)DB
  707 FORMAT(2X,'DISTANCE TO BORDER IS ',F5.1,' MILES')
      WRITE(6,708)XP1,YP1
  708 FORMAT(2X,'IF SPECIFIED, TARGET CO-ORDS ARE X=',F6.1,1X,',',1X
     1,'Y=',F6.1)
      WRITE(6,706)TIME
  706 FORMAT(2X,'TOTAL AIR TIME IS ',I4,' MINUTES')
      WRITE(6,320)
  320 FORMAT(1X,//,27X,'STATISTICAL DATA')
      WRITE(6,321)
  321 FORMAT(1X,/,2X,'SEARCH MODE')
      WRITE(6,322)
  322 FORMAT(1X,/,6X,'PERCENT OF TIME')
      WRITE(6,323)IANGX,STAT1
  323 FORMAT(10X,'1. F.O.V. INTERSECT APERATURE GREATER ',
     1'THAN ',I3,' DEG. ... ',F5.1)
      WRITE(6,324)PSA,STAT2
  324 FORMAT(10X,'2. COMMON AREA GREATER THAN ',F4.1,' PCT. OF ',
     1'SEARCH AREA .. ',F5.1)
      WRITE(6,331)STAT6
  331 FORMAT(6X,'PERCENT OF SEARCH AREA COVERED ',28('.'),' ',F5.1)
      WRITE(6,325)
  325 FORMAT(1X,/,2X,'TARGET MODE')
      WRITE(6,326)
```

```
326 FORMAT(1X,/,6X,'PERCENT OF TIME')
    WRITE(6,327)STAT3
327 FORMAT(10X,'1. TARGET IN RANGE OF TWO A/C ',
   125('.'),' ',F5.1)
    WRITE(6,328)IANG,STAT4
328 FORMAT(10X,'2. TWO A/C APERATURE GREATER THAN ',
   1I3,' DEG. ',12('.'),' ',F5.1)
    WRITE(6,329)INM,STAT5
329 FORMAT(10X,'3. VIEW OF TARGET WITHIN ',F5.1,' MIN. ',
   1'OF TWO A/C ',8('.'),' ',F5.1)
C
C     GRAPHICS DISPLAY OF STATISTICAL DATA
C
    CALL CTINIT(IDEV,ITCIR,14,IER)
    IF(IER.NE.0)OUTPUT(101)IER,'A1'
    ENCODE(16,300,ITEXT)
300 FORMAT('STATISTICAL DATA')
    CALL TEXTO(IDEV,ITEXT,4,3,25,3,2,IER)
    IF(IER.NE.0)OUTPUT(101)IER,'A2'
    ENCODE(12,301,ITEXT)
301 FORMAT('SEARCH MODE ')
    CALL TEXTO(IDEV,ITEXT,3,9,7,2,2,IER)
    IF(IER.NE.0)OUTPUT(101)IER,'A3'
    ENCODE(16,302,ITEXT)
302 FORMAT('PERCENT OF TIME ')
    CALL TEXTO(IDEV,ITEXT,4,12,12,1,2,IER)
    IF(IER.NE.0)OUTPUT(101)IER,'A4'
    ENCODE(60,303,ITEXT)IANGX,STAT1
303 FORMAT('1. F.O.V. INTERSECT APERATURE GREATER THAN ',I3,' DEG.',
   1' .. ',F5.1)
    CALL TEXTO(IDEV,ITEXT,15,14,18,1,2,IER)
    IF(IER.NE.0)OUTPUT(101)IER,'A5'
    ENCODE(60,304,ITEXT)PSA,STAT2
304 FORMAT('2. COMMON AREA GREATER THAN ',F4.1,' PCT. OF SEARCH ',
   1'AREA . ',F5.1)
    CALL TEXTO(IDEV,ITEXT,15,16,18,1,2,IER)
    IF(IER.NE.0)OUTPUT(101)IER,'A6'
    ENCODE(68,312,ITEXT)STAT6
312 FORMAT('PERCENT OF SEARCH AREA COVERED .......................',
   1'...... ',F5.1,'  ')
    CALL TEXTO(IDEV,ITEXT,17,18,12,1,2,IER)
    IF(IER.NE.0)OUTPUT(101)IER,'A6A'
    ENCODE(12,305,ITEXT)
305 FORMAT('TARGET MODE ')
    CALL TEXTO(IDEV,ITEXT,3,22,7,2,2,IER)
    IF(IER.NE.0)OUTPUT(101)IER,'A7'
    ENCODE(16,306,ITEXT)
306 FORMAT('PERCENT OF TIME ')
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      CALL TEXTO(IDEV,ITEXT,4,25,12,1,2,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'A8'
      ENCODE(60,307,ITEXT)STAT3
  307 FORMAT('1. TARGET IN RANGE OF TWO A/C .....................',
     1'... ',F5.1)
      CALL TEXTO(IDEV,ITEXT,15,27,18,1,2,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'A9'
      ENCODE(60,308,ITEXT)IANG,STAT4
  308 FORMAT('2. TWO A/C APERATURE GREATER THAN ',I3,' DEG. .....',
     1'...... ',F5.1)
      CALL TEXTO(IDEV,ITEXT,15,29,18,1,2,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'A10'
      ENCODE(60,309,ITEXT)INM,STAT5
  309 FORMAT('3. VIEW OF TARGET WITHIN ',F5.1,' MIN. OF TWO A/C',
     1' ....... ',F5.1)
      CALL TEXTO(IDEV,ITEXT,15,31,18,1,2,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'A11'
      ENCODE(24,310,ITEXT)
  310 FORMAT('(PUSH C/R TO CONTINUE)  ')
      CALL TEXTR(IDEV,ITEXT,6,39,36,1,2,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'A12'
  311 IF(MOD(ITDIR(12),8).EQ.0)GO TO 311
      RETURN
      END


      FUNCTION ARCOS(A)
      ARCOS=ATAN(SQRT(1.0-A**2)/A)
      RETURN
      END


      FUNCTION XINT(HX1,HX2,RO1,RO2)
C     THIS SUBROUTINE FINDS THE X INTERCEPT
      XINT=(RO1**2-RO2**2-HX1**2+HX2**2)/(2.0*(HX2-HX1))
      RETURN
      END


      FUNCTION YINT(XX,RD,POS)
C     THIS FUNCTION SUBROUTINE FINDS Y INTERCEPT
      YINT=SQRT(RD**2-(XX-POS)**2)
      RETURN
      END
```

```
      FUNCTION AREA(RAD)
      AREA=.5*3.14159*RAD**2
      RETURN
      END


      FUNCTION XAREA(RO,HO,RT,HT)
C     THIS SUBROUTINE FINDS THE TWO SECTOR COMMON AREA
      XAREA=(RO**2*ARCOS(1.0-HO/RO)-(RO-HO)*SQRT(2.0*RO*HO-HO**2)
     1+RT**2*ARCOS(1.0-HT/RT)-(RT-HT)*SQRT(2.0*RT*HT-HT**2))/2.0
      RETURN
      END


      FUNCTION XAREA1(RO,HO)
C     NOTE THAT XAREA(ARG1,ARG2,....) IS XAREA1(ARG1,ARG2) + XAREA1(ARG3,ARG4)
      XAREA1=(RO**2*ARCOS(1.0-HO/RO)-(RO-HO)*SQRT(2.0*RO*HO-HO**2))/2.0
      RETURN
      END


      FUNCTION APX(X,Y,P2,P3)
      S2=Y/(X-P2)
      S3=Y/(X-P3)
      IF(X.EQ.P2)S2=10000.0
      IF(X.EQ.P3)S3=10000.0
      SN=1.0
      IF(P3.LE.P2)SN=-1.0
      AARG=SN*((S2-S3)/(1.0+S2*S3))
      APX=ATAN(AARG)*360.0/6.283
      IF(APX.GT.0.0)APX=180.0-APX
      IF(APX.LT.0.0)APX=-APX
      RETURN
      END


      SUBROUTINE GPLOT(XY,M,IDEV,AP,DST)
C     GRAPHICS DISPLAY SUBROUTINE
C
      REAL INCR,INM
      INTEGER HITE1,HITE2,HITER,TIME
      COMMON POS1,POS2,POSR,HITE1,HITE2,HITER,R1,R2,RR,VEL1,VEL2,VELR,
     1TRNPTM,TRNPTP,TIME,INCR,IX,DB,XP1,XP2,XP3,YP1,YP2,YP3,NERR,IALL
     2,IANGX,IANG,INM,PSA,TP1,TP2,TPR,TM1,TM2,TMR
      DIMENSION XY(300,5),XC(300),YC(300),IGDIR(10),ITDIR(15)
      DIMENSION IVAL(9),IPAR(16),IFIGO(8),IMAGE(301),IAXIS(12),JDXY(6)
      DIMENSION IBOX(8),JXY(2),KJXY(6),AP(300,4),DST(300,7),JAXY(6)
      NAMELIST
```

```
      JON(I)=LIOR(IW,LLS(1,23-I))
      JOFF(I)=LAND(IW,LXOR(-1,LLS(1,23-I)))
      JSW(I)=LAND(IW,LLS(1,23-I))
      MSW(I)=LAND(ISW,LLS(1,23-I))
 1556 CONTINUE
      IW=JOFF(10)
      IW=JOFF(13)
      IW=JOFF(14)
      IW=JOFF(15)
      CALL DGINIT(IDEV,IGDIR,10,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'DTIKIT'
      CALL DTINIT(IDEV,ITDIR,12,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'DTINIT'
      ENCODE(36,1549,IPAR)
 1549 FORMAT('OPTIONS: 1.AREA DISPLAY....FNS 13    ')
      CALL TEXTO(IDEV,IPAR,9,16,15,2,3,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'S1'
C     ONLY THE APERATURE BTWN A/C TWO AND A/C REF IS DISPLAYED
C     PRINTOUT CONTAINS ALL APERATURES
      ENCODE(28,1550,IPAR)
 1550 FORMAT('2.APERATURE(2-R)....FNS 14  ')
      CALL TEXTO(IDEV,IPAR,7,19,33,2,3,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'S2'
      ENCODE(32,1551,IPAR)
 1551 FORMAT('3.POSSIBILITY OF FIX....FNS 15  ')
      CALL TEXTO(IDEV,IPAR,8,22,33,2,3,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'S3'
      ENCODE(40,1564,IPAR)
 1564 FORMAT('FNS 10 WILL RETURN PROGRAM TO THIS LIST ')
      CALL TEXTO(IDEV,IPAR,10,26,33,1,3,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'SZ'
 1545 CONTINUE
      IFIX=0
      CALL FNS(IDEV,ISW,IER)
      IW=LXOR(IW,ISW)
      I=1000
      CALL DELAY
      IF(JSW(13).NE.0)GO TO 1546
      IF(JSW(14).NE.0)GO TO 1547
      IF(JSW(15).NE.0)GO TO 1548
      GO TO 1545
 1546 CONTINUE
      IW=JOFF(13)
      IW=JOFF(10)
      DO 1511 J=1,M
      YC(J)=XY(J,2)
 1511 CONTINUE
      ENCODE(20,1557,IPAR)
```

```
1557 FORMAT('AREA                    ')
     GO TO 1552
1547 CONTINUE
     IW=JOFF(14)
     IW=JOFF(10)
     DO 1554 J=1,M
     YC(J)=AP(J,3)
1554 CONTINUE
     ENCODE(20,1558,IPAR)
1558 FORMAT('APERATURE(2-R)          ')
     GO TO 1552
1548 CONTINUE
     IFIX=1
     IW=JOFF(15)
     IW=JOFF(10)
     DO 1555 J=1,M
     YC(J)=0.0
     IF(R1.GE.DST(J,1).AND.R2.GE.DST(J,2).AND.DST(J,1).NE.0.0.
    1AND.DST(J,2).NE.0.0)YC(J)=1.0
     IF(R1.GE.DST(J,1).AND.RR.GE.DST(J,3).AND.DST(J,1).NE.0.0.
    1AND.DST(J,3).NE.0.0)YC(J)=1.0
     IF(R2.GE.DST(J,2).AND.RR.GE.DST(J,3).AND.DST(J,2).NE.0.0.
    1AND.DST(J,3).NE.0.0)YC(J)=1.0
1555 CONTINUE
     ENCODE(20,1559,IPAR)
1559 FORMAT('FIX..YES(1)..NO(0)      ')
1552 CONTINUE
     DO 1553 J=1,300
     XC(J)=XY(J,1)
1553 CONTINUE
C    AUTO-SCALING FOLLOWS
     XMAX=XC(1)
     DO 1502 N=2,M
     XMAX=AMAX(XC(N),XMAX)
1502 CONTINUE
     XMAX=XMAX+1.0
     XMIN=XC(1)
     DO 1506 N=2,M
     XMIN=AMIN(XC(N),XMIN)
1506 CONTINUE
     YMAX=YC(1)
     DO 1501 N=2,M
     YMAX=AMAX(YC(N),YMAX)
1501 CONTINUE
     YMIN=YC(1)
     DO 1507 N=2,M
     YMIN=AMIN(YC(N),YMIN)
1507 CONTINUE
```

```
      IF(IFIX.EQ.1)YMIN=-.1
      IF(IFIX.EQ.1)YMAX=1.1
  591 CALL DGINIT(IDEV,IGDIR,10,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'DGINIT'
      CALL DTINIT(IDEV,ITDIR,12,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'DTINIT'
      CALL TEXTO(IDEV,IPAR,5,5,5,1,3,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'S4'
      ENCODE(8,1560,IPAR)
 1560 FORMAT('TIME    ')
      CALL TEXTO(IDEV,IPAR,2,33,87,1,3)
      IF(IER.NE.0)OUTPUT(101)IER,'S5'
      DO 1505 K=1,301
      IMAGE(K)=0
 1505 CONTINUE
      CALL GRAPHC(IDEV,IMAGE,301,1,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'IMAGE'
      IMAGE(1)=IHEAD(0,8)
      EXX=(1.88*(XC(1)-XMIN))/(XMAX-XMIN)-.94
      YII=(1.59*(YC(1)-YMIN))/(YMAX-YMIN)-.65
      IMAGE(2)=IPACK(EXX,YII,0)
      DO 1504 K=1,M
      EX=(1.88*(XC(K)-XMIN))/(XMAX-XMIN)-.94
      YI=(1.59*(YC(K)-YMIN))/(YMAX-YMIN)-.65
      IMAGE(K+2)=IPACK(EX,YI,1)
 1504 CONTINUE
      CALL GRAPHC(IDEV,IMAGE,K+3,1,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'IMAGE1'
C     GRAPH BORDER CONSTRUCTION FOLLOWS
      IAXIS(1)=IHEAD(0,9)
      IAXIS(2)=IPACK(.95,-.66,0)
      IAXIS(3)=IPACK(.95,-.66,1)
      IAXIS(4)=IPACK(0.0,-.66,1)
      IAXIS(5)=IPACK(-.95,-.66,1)
      IAXIS(6)=IPACK(-.95,.14,1)
      IAXIS(7)=IPACK(-.95,.95,1)
      IAXIS(8)=IPACK(0.0,.95,1)
      IAXIS(9)=IPACK(.95,.95,1)
      IAXIS(10)=IPACK(.95,.14,1)
      IAXIS(11)=IPACK(.95,-.66,1)
      IAXIS(12)=0
      CALL GRAPHC(IDEV,IAXIS,12,2,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'IAXIS1'
      EXO=(-1.88*XMIN)/(XMAX-XMIN)-.94
      KB=2
      IF(EXO.GT..94.OR.EXO.LT.-.94)GO TO 1512
C     VERTICAL AXIS AT X=0 AND AXIS VALUE 0 ARE FORMED AS FOLLOWS
      IAXIS(1)=IHEAD(0,2)
```

```
      IAXIS(2)=IPACK(EXO,-.66,0)
      IAXIS(3)=IPACK(EXO,.14,1)
      IAXIS(4)=IPACK(EXO,.95,1)
      IAXIS(5)=0
      IAXIS(6)=0
      KB=KB+1
      CALL GRAPHO(IDEV,IAXIS,6,KB,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'IXO'
      IFIGO(1)=IHEAD(0,9)
      IFIGO(2)=IPACK(EXO-.0075,-.67,0)
      IFIGO(3)=IPACK(EXO+.0075,-.67,1)
      IFIGO(4)=IPACK(EXO+.0075,-.69,1)
      IFIGO(5)=IPACK(EXO-.0075,-.69,1)
      IFIGO(6)=IPACK(EXO-.0075,-.67,1)
      IFIGO(7)=0
      KB=KB+1
      CALL GRAPHO(IDEV,IFIGO,7,KB,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'IFIGO1'
 1512 CONTINUE
      YIO=(-1.59*YMIN)/(YMAX-YMIN)-.65
      IF(YIO.GT..94.OR.YIO.LT.-.65)GO TO 1513
C     HORIZ. AXIS AT Y=0 AND AXIS VALUE 0 ARE FORMED AS FOLLOWS
      IAXIS(1)=IHEAD(0,2)
      IAXIS(2)=IPACK(-.95,YIO,0)
      IAXIS(3)=IPACK(0.0,YIO,1)
      IAXIS(4)=IPACK(.95,YIO,1)
      IAXIS(5)=0
      IAXIS(6)=0
      KB=KB+1
      CALL GRAPHO(IDEV,IAXIS,6,KB,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'IYO'
      IFIGO(1)=IHEAD(0,9)
      IFIGO(2)=IPACK(-.96,YIO-.01,0)
      IFIGO(3)=IPACK(-.96,YIO+.01,1)
      IFIGO(4)=IPACK(-.975,YIO+.01,1)
      IFIGO(5)=IPACK(-.975,YIO-.01,1)
      IFIGO(6)=IPACK(-.96,YIO-.01,1)
      IFIGO(7)=0
      KB=KB+1
      CALL GRAPHO(IDEV,IFIGO,7,KB,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'KFIGO'
C     DISPLAY OF PARAMETER VALUES FOLLOW
 1513 ENCODE(56,1509,IPAR)HITE1,HITE2,HITER,DB
 1509 FORMAT('HITE1=',I6,'   HITE2=',I6,'   HITER=',I6
     1,'   DB=',F5.1,'    ')
      CALL TEXTO(IDEV,IPAR,14,34,12,1,2,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'IPAR1'
      ENCODE(64,1510,IPAR)R1,R2,RR,TRNPTM,TRNPTF
```

```
 1510 FORMAT('R1=',F5.1,'   R2=',F5.1,'   RR=',F5.1
     1,'   TRNPTM=',F6.1,'   TRNPTP=',F6.1,'  ')
      CALL TEXTO(IDEV,IPAR,16,35,12,1,2,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'IPAR3'
      ENCODE(52,1565,IPAR)POS1,POS2,POSR,TIME
 1565 FORMAT('POS1=',F6.1,'   POS2=',F6.1,'   POSR=',F6.1,
     1'   TIME=',I4)
      CALL TEXTO(IDEV,IPAR,13,36,12,1,2,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'IPAR4'
      ENCODE(40,1566,IPAR)VEL1,VEL2,VELR
 1566 FORMAT('VEL1=',F6.1,'   VEL2=',F6.1,'   VELR=',F6.1,' ')
      CALL TEXTO(IDEV,IPAR,10,37,12,1,2,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'IPAR5'
C     OPTION BOX IS FORMED
      IBCX(1)=IHEAD(0,10)
      IBCX(2)=IPACK(.33,-.90,0)
      IBCX(3)=IPACK(.33,-1.09,1)
      IBCX(4)=IPACK(1.2,-1.09,1)
      IBCX(5)=IPACK(1.2,-.90,1)
      IBCX(6)=IPACK(.33,-.90,1)
      IBCX(7)=0
      KB=KB+1
      CALL GRAPHC(IDEV,IBCX,7,KB,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'IB2'
      KB=KB+1
      IBLK=10
      GO TO 1517
 1523 CONTINUE
      IW=JOFF(3)
C     STATEMENTS TO 1517 REMOVE CURSOR ARRAY FROM SCREEN
      DO 1522 J=1,9
      IVAL(J)=-1
 1522 CONTINUE
      CALL TEXTO(IDEV,IVAL,9,2,52,1,2,IER)
      CALL TEXTO(IDEV,IVAL,9,3,52,1,2,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'IVALO'
      CALL TEXTO(IDEV,IVAL,9,4,52,1,2,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'IVALO'
      DO 1537 J=1,8
 1537 IBCX(J)=0
      CALL GRAPHC(IDEV,IBCX,8,KB,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'IB1'
 1517 CONTINUE
C     OPTION BOX IS FILLED
      ENCODE(32,1528,IPAR)
 1528 FORMAT('OPTIONS: 1.CURSOR ON--FNS 3      ')
      CALL TEXTO(IDEV,IPAR,8,37,62,1,3,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'OP1'
```

```
      ENCODE(24,1529,IPAR)
 1529 FORMAT('2.PRINTER PLOT--FNS 12  ')
      CALL TEXTO(IDEV,IPAR,6,38,71,1,3,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'CP2'
      ENCODE(24,1530,IPAR)
 1530 FORMAT('3.NAMELIST INPUT--FNS 11')
      CALL TEXTO(IDEV,IPAR,6,39,71,1,3,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'OP3'
C     A FNS SELECTION LOOP FOLLOWS
 1539 CALL FNS(IDEV,ISW,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'ISW'
      IW=LXOR(IW,ISW)
      I=1000
      CALL DELAY
      IF(JSW(3).NE.0)GO TO 1515
      IF(JSW(11).NE.0)GO TO 1516
      IF(JSW(12).NE.0)GO TO 1524
      IF(JSW(10).NE.0)GO TO 1556
      GO TO 1539
 1515 CONTINUE
C     OPTION BOX IS FILLED
      ENCODE(32,1531,IPAR)
 1531 FORMAT('OPTIONS: 1.MOVE FORWARD--FNS 7   ')
      CALL TEXTO(IDEV,IPAR,8,37,62,1,3,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'CP4'
      ENCODE(24,1532,IPAR)
 1532 FORMAT('2.MOVE BACK--FNS 8       ')
      CALL TEXTO(IDEV,IPAR,6,38,71,1,3,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'CP5'
      ENCODE(24,1533,IPAR)
 1533 FORMAT('3.CURSOR OFF--FNS 4      ')
      CALL TEXTO(IDEV,IPAR,6,39,71,1,3,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'OP6'
      IBLK=13
      IW=JOFF(3)
      IF(JSW(4).NE.0)IW=JOFF(4)
      K=M/2
      GO TO 1518
 1519 CONTINUE
      IF(K.EQ.M)GO TO 1518
      K=K+1
      GO TO 1518
 1520 CONTINUE
      IF(K.EQ.1)GO TO 1518
      K=K-1
 1518 CONTINUE
      EX=(1.88*(XC(K)-XMIN))/(XMAX-XMIN)-.94
      YI=(1.59*(YC(K)-YMIN))/(YMAX-YMIN)-.65
```

```
C       CURSOR IS FORMED AND XY REGISTERS DISPLAYED
        IBCX(1)=IHEAD(0,10)
        IBCX(2)=IPACK(EX,YI,0)
        IBCX(3)=IPACK(EX,YI,1)
        IBCX(4)=IPACK(EX,YI+.02,0)
        IBCX(5)=IPACK(EX-.02,YI-.02,1)
        IBCX(6)=IPACK(EX+.02,YI-.02,1)
        IBCX(7)=IPACK(EX,YI+.02,1)
        IBCX(8)=0
        CALL GRAPHC(IDEV,IBCX,8,KB,IER)
C       EXPRESS BUTTON
        IF(MSW(6).NE.0)GO TO 1538
        ENCODE(36,1541,IVAL)XY(K,4)
 1541   FORMAT('          CURRENT POS2: ',G12.6)
        CALL TEXTO(IDEV,IVAL,9,2,52,1,2,IER)
        ENCODE(36,1521,IVAL)XC(K)
 1521   FORMAT('CURRENT X AXIS VALUE: ',G12.6)
        CALL TEXTO(IDEV,IVAL,9,3,52,1,2,IER)
        ENCODE(36,1508,IVAL)YC(K)
 1508   FORMAT('CURRENT Y AXIS VALUE: ',G12.6)
        CALL TEXTO(IDEV,IVAL,9,4,52,1,2,IER)
 1538   CALL FNS(IDEV,ISW,IER)
        IF(IER.NE.0)OUTPUT(101)IER,'ISW2'
        IW=LXOR(IW,ISW)
        IF(JSW(4).NE.0)GO TO 1523
        IF(MSW(7).NE.0)GO TO 1519
        IF(MSW(8).NE.0)GO TO 1520
        GO TO 1518
 1524   CONTINUE
C       PRINTER PLOT EXECUTED
        IW=JOFF(12)
        ZMAX=XY(1,2)
        ZMIN=XY(1,2)
        DO 1562 J=2,M
        ZMIN=AMIN(XY(J,2),ZMIN)
        ZMAX=AMAX(XY(J,2),ZMAX)
 1562   CONTINUE
        PMAX=AP(1,1)
        PMIN=AP(1,1)
        DO 1563 K=1,3
        DO 1563 J=1,M
        PMIN=AMIN(AP(J,K),PMIN)
        PMAX=AMAX(AP(J,K),PMAX)
 1563   CONTINUE
        WRITE(6,206)
  206   FORMAT('1',//,4X,'TIME',8X,'AREA',8X,'POS1',7X,'POS2',7X,'POSR'
       1,7X,'AP12',7X,'AP1R',7X,'AP2R',8X,'1-T',8X,'2-T',8X,'R-T',/)
        MM=M/50
```

```
      IF(M.LT.50)MM=1
      IF(IALL.GT.0)MM=1
      DO 1527 J=1,M,MM
      WRITE(6,1526)XY(J,1),XY(J,2),XY(J,3),XY(J,4),XY(J,5),AP(J,1),
     1AP(J,2),AP(J,3),DST(J,1),DST(J,2),DST(J,3)
 1526 FORMAT(1X,F7.1,3X,F11.2,3X,9(F8.1,3X))
 1527 CONTINUE
      JXY(1)=1
      JXY(2)=2
      KJXY(1)=1
      KJXY(2)=3
      KJXY(3)=1
      KJXY(4)=4
      KJXY(5)=1
      KJXY(6)=5
      JAXY(1)=4
      JAXY(2)=1
      JAXY(3)=4
      JAXY(4)=2
      JAXY(5)=4
      JAXY(6)=3
      JDXY(1)=4
      JDXY(2)=1
      JDXY(3)=4
      JDXY(4)=2
      JDXY(5)=4
      JDXY(6)=3
      AM=M
      ENCODE(40,1540,IPAR)
 1540 FORMAT('TIME(MIN)  .VS.  OVERLAPPING AREA(SQ MI)')
      CALL VPLOT(XY,JXY,M,300,1,1,XMIN,XMAX,ZMIN,ZMAX,10,IPAR)
      ENCODE(44,1525,IPAR)
 1525 FORMAT('TIME(MIN)  .VS.  PLANE POSITION(MI)    + * ¬')
      CALL VPLOT(XY,KJXY,M,300,3,1,XMIN,XMAX,TRNPTM,TRNPTP,11,IPAR)
      ENCODE(52,1542,IPAR)
 1542 FORMAT('TIME(MIN)  .VS.  TWO PLANE APERATURE   12+, 1R*, 2R¬')
      CALL VPLOT(AP,JAXY,M,300,3,1,XMIN,XMAX,PMIN,PMAX,13,IPAR)
      ENCODE(60,1544,IPAR)
 1544 FORMAT('TIME(MIN)  .VS.  TARGET IN RANGE     YES 1.0, NO 0.0
     1  + * ¬  ')
      DO 1561 J=1,M
      AP(J,1)=0.1
      AP(J,2)=0.05
      AP(J,3)=0.0
      IF(DST(J,1).LT.R1)AP(J,1)=1.05
      IF(DST(J,2).LT.R2)AP(J,2)=1.0
      IF(DST(J,3).LT.RR)AP(J,3)=0.95
 1561 CONTINUE
```

```
      CALL VPLCT(AP,JDXY,M,300,3,1,XMIN,XMAX,-0.2,1.2,15,IPAR)
 1516 CONTINUE
      IALL=0
C     NAMELIST INPUT SECTION
C     OPTION BOX IS FILLED
      ENCODE(32,1534,IPAR)
 1534 FORMAT('OPTIONS: 1.INPUT PARAMETER--TTY ')
      CALL TEXTO(IDEV,IPAR,8,37,62,1,3,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'CP7'
      ENCODE(24,1535,IPAR)
 1535 FORMAT('2.EXECUTE--TYPE *C/R     ')
      CALLTEXTO(IDEV,IPAR,6,38,71,1,3,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'CP8'
      ENCODE(24,1536,IPAR)
 1536 FORMAT('3.END PROGRAM--TYPE IX=1')
      CALL TEXTO(IDEV,IPAR,6,39,71,1,3,IER)
      IF(IER.NE.0)OUTPUT(101)IER,'CP9'
      IW=JOFF(11)
      CALL GINPUT(IDEV,ITDIR,IBLK)
      CALL DGINIT(IDEV,IGDIR,10,IER)
      CALL DTINIT(IDEV,ITDIR,12,IER)
      RETURN
      END
```

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The ability of an airborne direction finding (DF) system to accurately fix target emitters depends heavily on the aircraft/target geometry and the duration of target emissions. Based on this, a computer model was developed to aid in the study of the effects of system parameters on fixing success and to help in constructing a procedure for finding optimum search patterns.

20.

The development of the computer model is traced from its foundation in current technology to its evolution into an interactive computer graphics system. With the computer model studies were made of the effect of one, two and three aircraft on fixing success. Also, simulation of DF missions using two aircraft were used to study the effects of target signal duration and target position on fixing success. As a result of the study a procedure using interactive graphics was developed to find optimum or near optimum patterns of flight for various airborne DF missions.

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